S. A. E. JOURNAL

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Edward P. Warner, *President* Coker F. Clarkson, *Secretary* C. B. Whittelsey, Jr., *Treasurer*

Vol. XXVI May, 1930 No. 5

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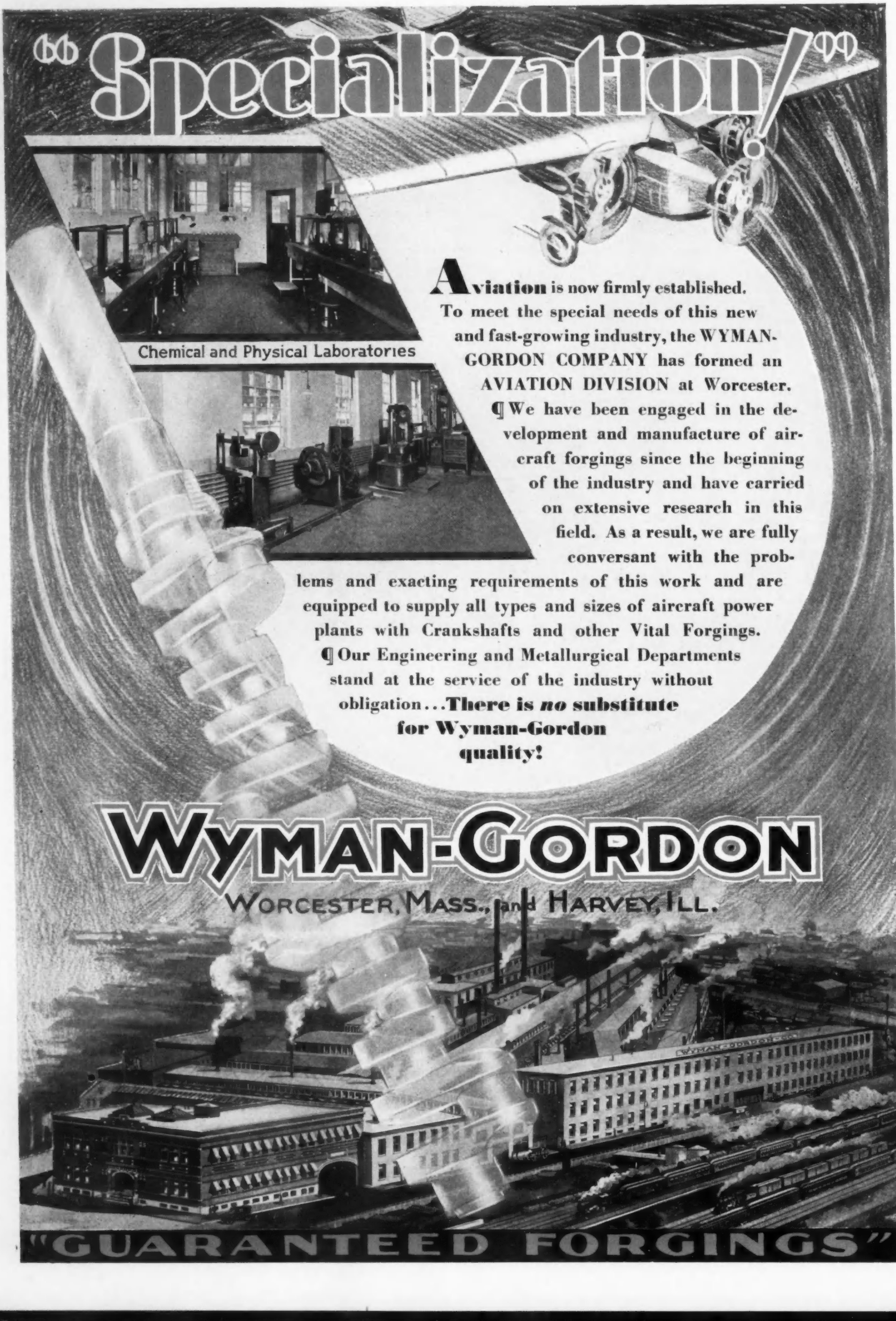
The purpose of meetings of the Society is largely to provide a forum for the presentation of straightforward and frank discussion. Discussion of this kind is encouraged. However, owing to the nature of the Society as an organization, it cannot be responsible for statements or opinions advanced in papers or in discussions at its meetings. The Constitution of the Society has long contained a provision to this effect.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S. A. E. JOURNAL

Vol. XXVI | May, 1930 | No. 5

Society To Celebrate Silver Anniversary

Summer Meeting Offers Splendid Technical Program at French Lick, and an Exhibition Portraying 25 Years of Progress

THE 1930 Summer Meeting, to be held at French Lick, May 25 to 29, promises to be an event of extraordinary interest and importance. A technical program of unusual merit has been arranged and, since this year marks the 25th anniversary of the founding of the Society, a fitting celebration will be staged.

Activities will begin on the afternoon of Sunday, May 25, with a Standards Session at 2 o'clock, at which matters of vital importance will be discussed. A General Session has been arranged by the Meetings Committee for the evening, with C. F. Kettering, general director of the General Motors Research Laboratories, as the only speaker. Mr. Kettering will talk about his trip to the Galapagos Islands, and everyone who plans to attend the Summer Meeting will look forward with lively anticipation to the Sunday evening session. No one who has ever heard "Ket" will willingly forego an opportunity of hearing him again.

Subjects of Three Monday Sessions

Monday morning will witness a division of interest, as some of the members will attend the Engine Session and others the Body Session, as these two sessions are to be held concurrently. Three papers have been prepared for presentation at the Engine Session: Powerplant Economics, by Alex Taub, of the Chevrolet Motor Co.; Bearing Bronzes with Additions of Zinc, Phosphorus, Nickel and Antimony, by E. M. Staples, R. L. Dowdell and C. E. Eggenschwiler, of the Bureau of Standards; and Combustion-Chamber Progress, by Alex Taub.

Those who attend the Body Session will hear Prof. F. W. Pawlowski, of the University of Michigan, talk on Wind Resistance, and a most pertinent discussion of the Psychology of Riding Comfort by G. C. Brandenburg and Ammon Swope, of Purdue University. At this session Dr. F. A. Moss, of George Washington University, will present a report on the riding-qualities investigation that he has been conducting. All who have heard Dr. Moss talk on this subject will look forward to his report with much pleasure.

President Edward P. Warner will preside at the Business Session, which will convene on Monday evening and is to be followed by a session devoted to transmission problems. Herbert Chase, associate editor of *American Machinist*, is scheduled to deliver the principal paper at this session. His general survey of the subject will be followed by several short papers, each dealing with some special type of gear. The authors of these are F. C. Pearson, of the Reo Motor Car Co.; and W. R. Griswold, of the Packard Motor Car Co. A lively discussion is expected to follow the papers.

A Heavy-Duty Day

A Diesel-Engine Session and a Brake Session will be held simultaneously on Tuesday morning. Those who attend the former will enjoy hearing talks by C. L. Cummins, of the Cummins Engine Co., and H. D. Hill, of the Hill Diesel Engine Co. The papers at the Brake Session are to be presented by A. W. Frehse, of the Chevrolet Motor Co., and John Whyte, of the Warner Electric Brake Corp.

Tuesday evening will be devoted to a consideration of motor-truck and motorcoach problems. L. R. Buckendale, of the Timken-Detroit Axle Co., will talk about the Application of Balloon-Tire Equipment on Motorcoaches and Trucks, and A. J. Scaife, of the White Motor Co., will tell about Some Power and Speed Problems in Motorcoach and Motor-Truck Design.

Aircraft Engine and Transportation Sessions

Two very interesting sessions are scheduled concurrently for Wednesday morning. At the Aircraft-Engine Session two papers are to be given, one on The Effect of Airplane Fuel-Line Design on Vapor Lock, prepared by O. C. Bridgeman and H. S. White, of the Bureau of Standards, and the other one on Aircraft Engine Installation, by Arthur Nutt, of the Curtiss Aeroplane & Motor Co., Inc.

At the Transportation Session, H. V. Middleworth, of the Consolidated Gas Co., will take

MAIN ENTRANCE PORTICO OF THE FRENCH LICK SPRINGS HOTEL

Meetings Calendar

National Meetings of the Society

Metropolitan Aeronautic—May 6 and 7
Park Central Hotel, New York City

Summer Meeting—May 25 to 29
French Lick Springs

West Coast Transportation—September or October
San Francisco

Chicago Aeronautic—Aug. 26 to 28
(In conjunction with National Air Races)

Production—Oct. 8 and 9
Book-Cadillac Hotel, Detroit

Transportation—Oct. 22 to 24
Pittsburgh

May Section Meetings

Baltimore Section—May 21
Engineers Club; Dinner, 6.30 p.m.
Subject—Maintenance

Buffalo Section—May 6
Markeen Hotel; Get-together Dinner, 7.30 p.m.
Subject—New Models

Canadian Section—May 21
Royal York Hotel, Toronto; Dinner, 6.30 p.m.
Speaker—A. J. Baker, Chief Engineer, Willys-Overland Co.

Cleveland Section—May 12
Hotel Cleveland; Dinner, 6.30 p.m.
Aluminum Alloys—Frank Jardine, Aluminum Co. of America.

Detroit Section—May 12
Book-Cadillac Hotel; Dinner, 6.30 p.m.

Indiana Section—May 15
Hotel Claypool, Indianapolis
The Cars of the 1930 500-Mile Race

Metropolitan Section—May 6 and 7
Park Central Hotel
National Aeronautic Meetings, sponsored by Metropolitan Section
Dinner, 6.30 p.m., Wednesday, May 7

Milwaukee Section—May 7
Milwaukee Athletic Club; Dinner, 6.30 p.m.
Significance of Tests for Motor Fuels—R. E. Wilson, Standard Oil Co. of Indiana
The Story of Gasoline—Motion Pictures from Bureau of Mines

New England Section—May 14
Afternoon Inspection Trip to George Lawley & Son Corp. plant at Neponset, Mass. Shore dinner followed by technical meeting, location to be announced

Northern California Section—May (?)
Ethyl Gasoline—Howard A. Reinhart, Sales Engineer, Ethyl Gasoline Corp.

Northwest Section—May 9
Bergonian Hotel, Seattle, Wash.; Dinner, 6.30 p.m.
Diesel Engines—Prof. Fred. G. Baender, Oregon State College

Oregon Section—May 9
Multnomah Hotel, Portland; Dinner, 6.30 p.m.
Air Transportation—G. A. Rathert, Chief Engineer, Breese Aircraft Corp.
Also an exhibit of airplane parts

Philadelphia Section—May 5
Philadelphia Automobile Trade Association Rooms; Dinner, 6.30 p.m.
Indianapolis Race Predictions—William F. Sturm, Manager of Kaye Don

St. Louis Section
No meeting scheduled.

Southern California Section—May 9
City Club, Los Angeles; Dinner, 6.15 p.m.
Influence of the Motor-Vehicle on Highway Design and Construction
Governing Features of Highway Location and Design, and Laboratory and Field Control during Construction—T. E. Stanton, Materials and Research Engineer, State of California
Matters Relating to City Streets—R. W. Stewart, Deputy City Engineer, Los Angeles

Syracuse Section—Date Unsettled
Business Meeting

Summer Meeting Technical Program

May 25-29, 1930 **French Lick, Ind.**

Sunday, May 25

2:00 P. M.—STANDARDS

8:30 P. M.—GENERAL SESSION

The Galapagos Islands
C. F. Kettering, General Motors Corp.

Monday, May 26

10:00 A. M.—ENGINES

Powerplant Economics
Alex Taub, Chevrolet Motor Co.
Bearing Bronzes with Additions of Zinc, Phosphorus, Nickel and Antimony
E. M. Staples, R. L. Dowdell and C. E. Eggenschwiler, Bureau of Standards
Combustion Chamber Progress—A Review
Alex Taub, Chevrolet Motor Co.

10:00 A. M.—BODIES

Wind Resistance
F. W. Pawlowski, University of Michigan
The Psychology of Riding Qualities
G. C. Brandenburg and Ammon Swope, Purdue University
Riding Qualities
Dr. F. A. Moss, George Washington University

8:00 P. M.—BUSINESS SESSION

8:30 P. M.—TRANSMISSIONS

Comments and Criticism of American Passenger-Car Gearsets
Herbert Chase, *American Machinist*
Constant Mesh or Sliding Gear Transmissions
F. C. Pearson, Reo Motor Car Co.
Spur Gears
W. R. Griswold, Packard Motor Car Co.

Tuesday, May 27

10:00 A. M.—DIESEL ENGINES

Diesel Engines for Automobiles
C. L. Cummins, Cummins Engine Co.
Small Diesel Engines
H. D. Hill, Hill Diesel Engine Co.

10:00 A. M.—BRAKES

Fundamentals of Brake Design
A. W. Frehse, Chevrolet Motor Co.
Electric Brakes for Cars, Trucks and Trailers
John Whyte, Warner Electric Brake Corp.

2:00 P. M.—FIELD DAY

8:30 P. M.—MOTOR-TRUCKS AND MOTORCOACHES

Application of Balloon Tire Equipment on Motorcoaches and Trucks
L. R. Buckendale, Timken-Detroit Axle Co.
Some Power and Speed Problems in Motorcoach and Motor-Truck Design
A. J. Scaife, White Motor Co.

Wednesday, May 28

10:00 A. M.—AIRCRAFT AND AIRCRAFT ENGINES

Effect of Airplane Fuel Line Design on Vapor Lock
O. C. Bridgeman and H. S. White, Bureau of Standards
Aircraft Engine Installation
Arthur Nutt, Curtiss Aeroplane & Motor Co.

10:00 A. M.—TRANSPORTATION

Self Maintenance as Compared with Service Station Maintenance
H. V. Middleworth, Consolidated Gas Co.
Prepared Discussion by
Joseph Siegel, Metropolitan Distributors, Inc.
Martin Schreiber, Public Service Coordinated Transport
O. M. Brede, General Motors Truck Co.
H. C. Marble, The White Co.
F. B Whittemore, Mack-International Motor Truck Corp.
F. K. Glynn, American Tel. & Tel. Co.

2:00 P. M. 25TH ANNIVERSARY PAGEANT

8:30 P. M.—25TH ANNIVERSARY CELEBRATION

10:30 P. M.—GRAND BALL

Thursday, May 29

10:00 A. M.—AIRCRAFT AND AIRCRAFT ENGINES

A Comparative Study of Powerplant Engineering for Motor-Cars and Aircraft
H. M. Crane, General Motors Corp.
Speed
Lieut. Carl B. Harper, Bureau of Aeronautics

10:00 A. M.—RESEARCH

Engine Acceleration
C. S. Bruce, Bureau of Standards
Effect of Weathering in the Tank on the Vapor Locking Tendency of Gasolines
O. C. Bridgeman and E. W. Aldrich, Bureau of Standards
Vapor Lock
W. C. Bauer, Standard Oil Co.

up the question of Self Maintenance as Compared with Service-Station Maintenance. Prepared discussion of this topic is to be submitted by Joseph Siegel, of Metropolitan Distributors, Inc.; Martin Schreiber, of the Public Service Coordinated Transport; O. M. Brede, of the General Motors Truck Co.; H. C. Marble, of the White Co.; F. B. Whittemore, of the Mack-International Motor Truck Corp.; and F. K. Glynn, of the American Telephone & Telegraph Co.

The 25th Anniversary Dinner and dance, arranged for Wednesday evening, will be a gala occasion. The "old timers" will be honored at the dinner and a delightful evening is anticipated.

Aircraft and Research Sessions

The last of the technical sessions will be held on Thursday morning. At the Aircraft Session, H. M. Crane, of the

(*Concluded on p.* 650)

Metropolitan Aeronautic Meeting

Four Sessions and Dinner To Be Held at the Park Central Hotel on May 6 and 7

A TWO-DAY aeronautic meeting sponsored by the Aeronautic Division of the Metropolitan Section of the Society will be held May 6 and 7 at the Park Central Hotel, New York City, during the week of the New York Aircraft Salon at Madison Square Garden. Technical sessions will be held mornings and afternoons, and the meeting will be concluded by a joint dinner with the Aeronautical Chamber of Commerce on the second night.

The first day will be devoted to aircraft engines and marine air-transport, and of the two technical sessions on Wednesday, May 7, one will be on aircraft design, and the other session on research, experiment and manufacture.

At the Aircraft Banquet which is to start at 6:30 Wednesday night, the guest and speaker of the evening will be F. B. Rentschler, president of the Aeronautical Chamber of Commerce of America.

The speakers at the technical sessions and banquet are all prominent men in their respective fields, and the subjects are such as to be of great interest to engineers in all aeronautic branches.

A complete program is printed herewith. Preprints of the papers, with the exception of the dinner address, will be available at the meeting.

Metropolitan Aeronautic-Meeting Program

Grand Ball Room, Park Central Hotel, New York City

May 6 and 7, 1930

Tuesday, May 6

10.30 A.M.—ENGINES

George W. Dunham, Chairman (Past President S.A.E.)

In-Line Liquid-Cooled versus Air-Cooled Engines
George J. Mead, Vice-President, Pratt & Whitney Aircraft Co.

In-Line versus Radial Engines
W. F. Davis, Chief Engineer, Fairchild Engine Corp.

2.30 P.M.—MARINE AIR-TRANSPORT

Virginius E. Clark, Aviation Corp., Chairman

Amphibian Design and Transportation
Giuseppe M. Bellanca, President, Bellanca Aircraft Corp.

Transoceanic Air Travel
Jerome C. Hunsaker, Vice-President, Goodyear Zeppelin Corp.

Wednesday, May 7

10.30 A.M.—AIRCRAFT DESIGN

Edward V. Rickenbacker, Chairman, (Vice-President Fokker Aircraft Corp.)

The Dornier Do-X Flying Ship
Lieut. C. H. Schildhauer, Dornier Corp. of America

The New Autogiro
W. Laurence LePage, Kellett Aircraft Corp.

2.30 P.M.—RESEARCH, EXPERIMENT AND MANUFACTURE

Theeodore P. Wright, Chairman, (Chief Engineer, Curtiss Aeroplane & Motor Co.)

Speed Flying
Lieut. A. J. Williams, Jr., U. S. N.

Commercial Aviation in the United States from the Point of View of an Air Corps Officer
Major Leslie MacDill, United States Air Corps

Wednesday Evening

6.30 P.M.—AIRCRAFT BANQUET

Sponsored by the Aeronautic Division of the Metropolitan Section of the S.A.E., in conjunction with the Aeronautical Chamber of Commerce of America

Henry S. Breckinridge, Toastmaster

Transportation versus Air Circus
F. B. Rentschler, President, Aeronautical Chamber of Commerce of America

Airplane and Glider Development Evidenced

Detroit Aeronautic Meeting and Aircraft Show Well Staged—Meetings' Papers, Glider Flights and Ford-Airport Visit Compel Large Attendance—S.A.E. Standards Featured

DETROIT went aviation mad during the week of April 7 to 12. The Society held a peppy three-day Aeronautic Meeting there and the city's third All-American Aircraft Show was in progress. It was an occasion profitable to all who attended, and about 900 members and guests took advantage of this wonderful opportunity.

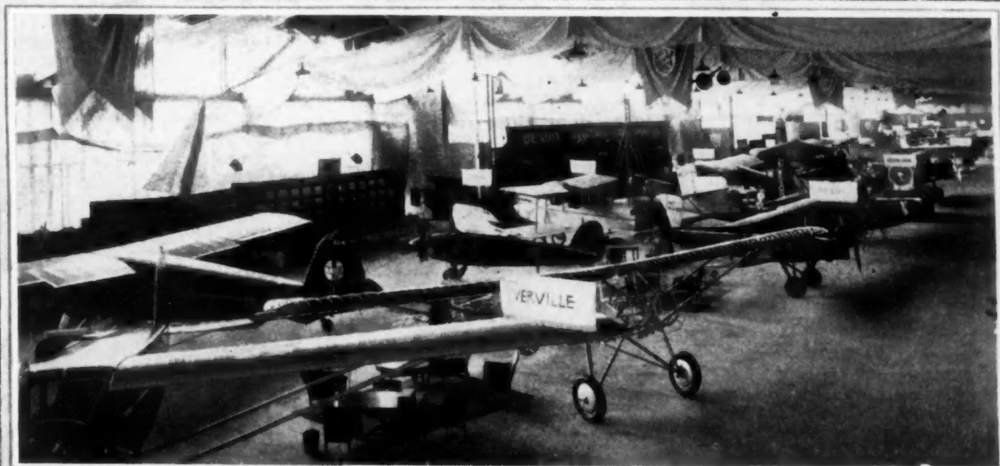
Sessions on aircraft engines, aircraft in general and in particular, and on glider construction, were held Tuesday and Wednesday, April 8 and 9, at the Book-Cadillac Hotel, the glider demonstrations being made on Wednesday afternoon at the Municipal Airport. The Aircraft Banquet occupied Tuesday evening, April 8, and April 10 was devoted exclusively to an inspection trip which included the Ford automobile plant, historical village, airport and aircraft factory, a luncheon being provided at the Ford administration building. The S.A.E. Standards booth at the Aircraft Show encouraged further adoption of aircraft-parts standardization.

All-American Aircraft-Show

Winged monarchs of the air held sway in the capital of motordom while Detroit engaged in its double celebration that opened its third annual All-American Aircraft-Show and, at the same time, dedicated the Municipal Airport and its new $1,000,000 hangar and exposition building. The flying craft on exhibition ranged from a diminutive single-seater airplane selling at $1,500 to a giant 32-passenger air-palace which was reported to have been purchased for the personal use of its owner at a price of $150,000. The interior decorations of this air queen were most lavish and were said to have cost $50,000. The plane is equipped with four sleeping-berths, a complete kitchen including an ice-box and a stove, and has a completely furnished lounging room. Practically nothing inside its cabin resembles the conventional airplane; rather, it appears to be a luxuriously appointed apartment.

The Show brought together the largest fleet of American-built commercial aircraft ever assembled. Eighty-five airplanes were exhibited in the show building and as many, if not more, were parked on the airport for demonstration purposes. The Show was sponsored by the Detroit Board of Commerce and sanctioned by the Aeronautical Chamber of Commerce, Inc. It was managed by practically the same group which staged the two previous shows. Edward S. Evans was chairman of the Show Committee.

Ray Cooper was Show manager. "The manufacturers wanted a show on an airport so that they would have no difficulties in giving prompt demonstrations to prospective purchasers," he said. "They also sensed the necessity for having a building specially designed for the housing of aircraft, one that would permit the entry of even the largest airplane without necessitating its being dismantled."



INTERIOR VIEWS OF THE DETROIT ALL-AMERICAN AIRCRAFT SHOW

The Views Shown Indicate the Characteristics of the Entire Exhibition. Manager Ray Cooper Was Quoted as Saying That the Attendance Was the Largest Since Aircraft Shows Were Inaugurated in Detroit

Diesel Aircraft-Engine Exhibited

The Show served as the stage for the first public exhibition of the new Packard Diesel aircraft-engine recently placed in production. A specially plated and burnished cut-away model was shown mounted on a turntable set on a high pedestal. The engine was operating to show the action of its various component parts, the propeller was turning, and the entire exhibit revolved so that all might see it in its entirety, from all angles. Floodlights from the four corners of the booth illuminated the engine, which thus constituted one of the most beautiful exhibits of its kind that has so far been displayed. L. M. Woolson, its designer, presented a description of the engine at the S.A.E. Aircraft Banquet.

Cooperation Greatly Appreciated

An expression of appreciation and thanks is hereby tendered by the Society to all those who contributed toward the success of this meeting. Among these are Miss Amelia Earhart, who graced the speaker's table at the Banquet; Sir Hubert Wilkins, who contributed a racy description of his Arctic and Antarctic flights; Toastmaster Carl B. Fritsche, whose geniality and apropos remarks made everyone feel at ease; and L. M. Woolson who contributed an extremely valuable paper.

The work of the authors who presented the papers at the various Sessions and that of the members and guests who contributed discussion was exceptionally good. Ray Cooper, manager of the Aircraft Show, also deserves the vote of thanks accorded him herewith for his cooperation.

The chairmen who conducted the several sessions are to be congratulated on having stimulated much valuable discussion. As stated in the following reports of each session these were: President Edward P. Warner, aircraft engines; C. J. McCarthy, aircraft; and Prof. P. Altman, gliders. The distances between the Hotel and the Municipal and Ford Airports are great; therefore, thanks are extended also to all those who contributed toward furnishing motor-coach and other means of transportation.

An aeronautic meeting of the Metropolitan Section is scheduled to be held in New York City May 6 and 7, details of which appear on p. 532.

Aircraft and aircraft-engine sessions are to be held at the Semi-Annual Meeting at French Lick Springs, Ind., May 25 to 29 inclusive.

In conjunction with the National Air Races at Chicago, the Society and the Chicago Section will stage aeronautic-meeting sessions at the Palmer House Aug. 26 to 28.

Engine Session Opens Meeting

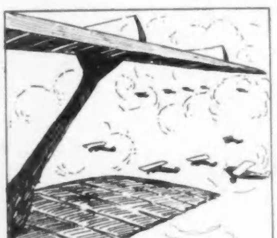
Geared Superchargers and Airplane-Engine Requirements Are Studied Intensively

THE FIRST session of the Detroit Aeronautic Meeting of the Society, devoted to aircraft engines, convened at the Book-Cadillac Hotel, Tuesday morning, April 8, with President Edward P. Warner presiding as acting chairman on account of the unavoidable absence of Roland Chilton. More than 100 members and guests were present.

In opening the meeting, President Warner said in effect that the Aeronautic Meetings of the Society have been steadily growing in popularity in the aeronautical industry and have been claiming constantly more serious attention from the aeronautical engineers, as well as from the executives, the sales managers, and all those whose own personal future depends upon the quality of the product that the aircraft industry can offer to its potential purchasers.

"We argue," he continued, "over the relative importance of the immediate and the more remote future, upon the relative significance of the immediate disposition of the product now in hand, and the plans that we are, or should be making for the product of four or five years hence. Manifestly, if we are unable to sell anything in the present, we will not live to sell anything in the future. We must carry on from day to day, but we are taking a dangerous risk. In fact, we are putting ourselves in an impossible position if we confine our attention to day-to-day development and if, interested as most of us primarily are in the commercial development of aviation, we allow ourselves to neglect either what has been done in foreign countries or what has been done in the military sphere."

It has been the history of many contributions to the aeronautical art that they have first flowered in the laboratory where they have offered little or no initial prospect of practical applicability, that they have become the subject of military experiment, and ultimately of military employment, still without seeming commercial availability. They have, ultimately, by persistent effort on the part of their enthusiastic backers and of the engineers responsible for the work upon their development, made their way into the airplane of peaceful pursuits, the speaker said.



"A good example of that is offered by Dr. Moss' paper, soon to be presented. I do not know just how long the idea of pushing the mixture into the cylinder of an engine, instead of allowing it to be inhaled, has been entertained in theory. I recall that it was the subject of very active discussion during the war, and that there was a great deal of experimenting in the United States and in Europe with superchargers of every imaginable design, and with rotors of every imaginable material from compressed, vulcanized fiber, essentially a *papier maché*, to vulcanized rubber, bakelite, and all kinds of metals. The initial experiments were not very encouraging, but there were those who had had their faith aroused to the point where they were willing and insistent in carrying on in spite of those early difficulties. Perhaps the most persistent of them all is Dr. Sanford A. Moss, of the West Lynn, Mass., research laboratories of the General Electric Co. This company, having had considerable experience with centrifugal compressors, was naturally invoked as an aid in the development of the first centrifugal superchargers in this Country. Dr. Moss took the work over for the company and has been at it ever since.

"It is no news to anyone present that the supercharger, which was for a long time an accessory, and one of somewhat dubious value, except in the making of altitude records and in the building of high-altitude pursuit-ships, and perhaps in the building of vehicles which competed upon the track or else were under rules limiting piston-displacement, has come almost at a bound into the sphere of practical politics and of practical utility in all commercial as well as military flying, by the introduction of the rotary distributor and the incorporation of supercharging as a fundamental and permanent part of the engine. The story of supercharger development and of its present status, as viewed by a representative of the laboratories and shops that have been most continuously in touch with the particular type of supercharger to which the paper refers, the geared centrifugal supercharger, will now be told by Dr. Moss."

Geared Centrifugal Superchargers Advocated

Four independent purposes for the geared centrifugal supercharger, now in extensive use on commercial airplane engines, were listed by Dr. Moss, who stated also that these are actually centrifugal compressors geared from the engine crankshaft and having such rotative speed and design detail as to produce an appreciable pressure-rise. A system of cooperation between the en-

gine and the supercharger builders has been devised so that the supercharger is an integral part of the engine. The high-speed impeller is the only part that the supercharger manufacturer supplies. The system enables the engine builder to have the benefit of a supercharger carefully designed and superintended by specialists in the art.

After describing the centrifugal compressor, which builds up at the diffuser exit a pressure appreciably greater than that at the impeller exit because of the conversion of velocity into pressure, Dr. Moss mentioned some details of the history of supercharger development and commented upon the design of the built-in supercharger.

Stating that the carbureter arrangement in supercharged engines is simple, there being but a single path from the atmosphere to the inlet of the supercharger impeller, the speaker mentioned the benefit obtained by using rotative rather than reciprocating devices as regards a tendency toward compact design, as well as the higher speeds attainable by moving parts that are perfectly balanced rotating wheels, and remarked also upon the importance of selecting high-quality material and maintaining adequate inspection.

As used in airplane engines, one of the most important advantages of the supercharger is the improvement in distribution, according to Dr. Moss, who enlarged upon this subject and discussed also the theory of supercharging an engine at sea-level, inclusive of the power limit for supercharging. Other subjects treated included supercharging at altitude, the maintenance of carbureter efficiency, and speed variation with a supercharged engine. In conclusion, Dr. Moss remarked that any good engine not equipped with a supercharger will be a better engine if a supercharger is installed.

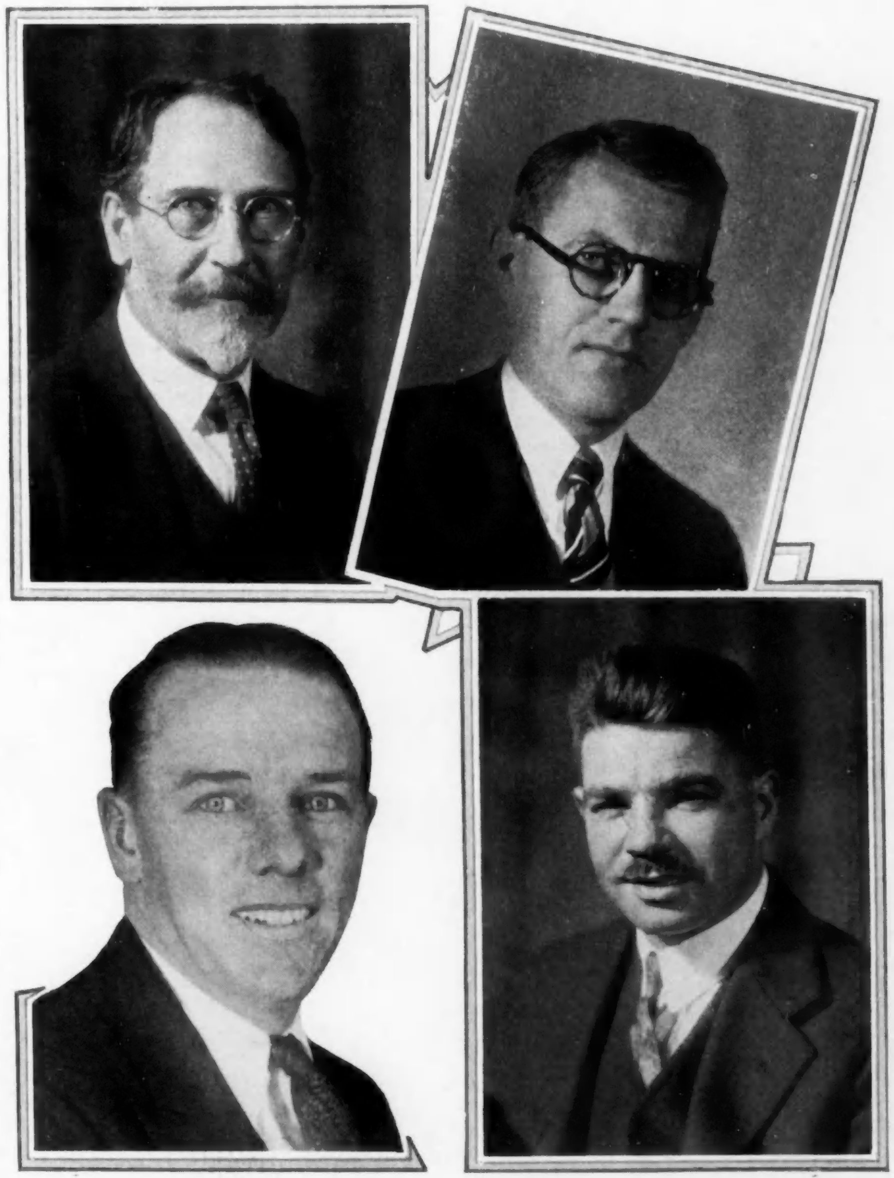
Differences of Opinion Stated

President Warner then called for the presentation of prepared discussion by Arthur Nutt, chief engineer of the motor division of the Curtiss Aeroplane & Motor Co., which was read by Marsden Ware, of the same company.

Mr. Nutt described briefly a partly built-in supercharger constructed in 1917 for installation on the Curtiss K-12 engine, and the history connected with it. This, in Mr. Nutt's opinion, was the first engine in the United States to be equipped with a gear-driven centrifugal supercharger. It was not until 1924 that a radial engine was built with a gear-driven supercharger similar to those in present use. He stated also that actual practice has shown that engines with superchargers built in have very much more complicated accessory-drive housings for which the supercharger construction is directly responsible.

Other subjects taken up by Mr. Nutt included whether the supercharged engine has any better distribution than an unsupercharged engine with a suitable type of manifold, the obtaining of satisfactory mean effective pressure with slightly less weight than could be obtained by the use of a multi-barrel carbureter, and separate passages on multi-cylinder radial-engines having seven or more cylinders by use of a centrifugal supercharger. In general, he commented on the supercharger to the effect that, if the supercharger can be eliminated from the commercial engine without sacrificing too much performance, even at the expense of some added weight, that engine would be a better engine without the supercharger, although this statement cannot be too broad inasmuch as each engine must be discussed by itself so far as the application of a supercharger to it is concerned, depending on the type of engine and the kind of service to which the engine is to be subjected. For example, it may be said that if a military engine is a good engine unsupercharged, it is a better military engine unsupercharged, which statement does not apply to commercial engines necessarily.

High points brought out in the oral discussion included remarks by Dr. Moss, in reply to a question from R. L. Livingstone, that the diffuser curves must be very accurate and that the impeller curves must also be given careful attention, but mainly as a matter of



AUTHORS OF PAPERS AT THE ENGINE SESSION

Dr. Sanford A. Moss (Upper Left), of the Research Laboratories of the General Electric Co., Whose Paper on Geared Centrifugal Superchargers for Airplane Engines Was Discussed by Arthur Nutt (Upper Right), of the Curtiss Aeroplane & Motor Co. E. P. Lott (Lower Left) and Wesley M. Smith (Lower Right), of National Air Transport, Inc., Were Co-Authors of the Paper on Airplane-Engine Requirements from an Operator's Viewpoint

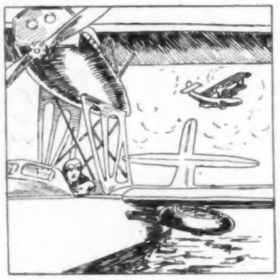
easier machining. The fluid flows out of the impeller into the diffuser, he said, and there the fluid is traveling at a very high velocity and must be slowed down so that the velocity will be converted into pressure.

Power Required for Supercharging

In reply to the query regarding how much power is required to drive a supercharger, Dr. Moss said that the power is no more than the power due to that same amount of compression in the cylinder itself, taking account of the engine efficiency; that is, the first stroke in a four-cycle engine is a compression stroke, and it has a certain amount of compression with a certain efficiency, bearing in mind the engine friction. The centrifugal supercharger has nearly equal efficiency, and has an added amount of compression.

A comparison of the J-5 and the J-6 engines, if carefully made, will show that the J-6 engine has more power with wide-open throttle, Dr. Moss remarked. It must not be forgotten that the entire amount of supercharging is not available for actual increased power above sea-level. In some cases, as Mr. Nutt pointed out, there has been some impairment of efficiency of the intake passage and the carbureter passage because of their being too small. Some engineers have used superchargers to overcome that disadvantage.

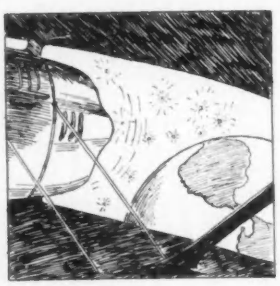
It is not good practice to use a poor intake and then use a supercharger to overcome it. If that is done, there may be a loss of power; but, if one is careful to use full-sized passages, so that no power will be wasted that must be overcome with a supercharger, then one gets the increased power which is specified; and Dr. Moss stated that the result of careful tests of the mean effective pressure show that.



Power, Economy and Reliability Needed

George W. Lewis, of the National Advisory committee for Aeronautics, said that the ideal supercharger is one that is very reliable and absorbs no power until the pilot needs it. In such case, the pilot uses the supercharger and gets the excess power. Power, economy and reliability are needed. Therefore, investigations are being made at present to find out just what effect supercharging has on the compression ratios of engines having ratios of 4.0, 4.5, 5.0, 5.5 and 6.0 to 1, and then supercharging them. It may be possible, he said, to get economies at those low compression-ratios by suitable means and then to use a supercharger so that one can obtain the excess power and still get inherent reliability in an engine that has been designed to have a low compression-ratio.

President Warner said that the problems of air transportation and of aerial operation in general are numerous and diversified, but none is more important than the establishment of a continuously harmonious understanding and a continuous cooperation between the operator and the manufacturer of equipment. There are a great many advantages in having the airplane structure and the powerplant come from different factories, he continued. The problems of design and construction are essentially different, and they have grown up along separate although parallel lines as two more or less distinct industries; but, against those advantages, there is one disadvantage in that it becomes peculiarly easy for the airplane and the engine representatives to fancy themselves as standing on opposite sides of an impenetrable barrier. The operator, if any reconciling factor is necessary, should provide the reconciliation, because it makes no difference to him as to what breaks down.



Airplane-Engine Requirements

In the course of presenting the paper on Airplane - Engine Requirements from an Operator's Viewpoint, by E. P. Lott and Wesley M. Smith, read by Mr. Lott, it was stated in part that air-transport operation is unfortunately the proving ground for the products of both the airplane manufacturer and the airplane - engine manufacturer engaged in producing equipment for use in the National air-transport branch of the aircraft industry. This duty is thrust upon us to get the service out of our equipment which we, as purchasers, should expect to find built into it when delivered to us, he said. In groping about for reasons for this fact, we find several possibilities, namely:

(1) A lack of proper understanding between the manufacturer and purchaser as to just what is required of the airplanes being purchased
(2) A lack of ability of the manufacturer to deliver what he fondly hoped he could when he obligated himself to the job, including improper appreciation of the importance of details by the designers of both airplane and engine
(3) A lack of ability of the operator to use and properly care for the equipment furnished
(4) The varied uses to which different operators must put their equipment, many of them containing factors opposed to one another

Part of the paper was confined to a discussion of the foregoing possibilities.

In conclusion, Mr. Lott stated that most engine manufacturers apparently consider only weight, horsepower and fuel consumption. More consideration should be given durability, he remarked, and more use could be made by airplane and accessory manufacturers of the S.A.E. HANDBOOK relating to Standards. The operators can well afford to cooperate and decide on the type of pipe fittings they should use for plumbing installations and instrument connections, in the author's opinion, as well as on standard cockpit-layouts and many other items which probably tend to drive the manufacturer crazy when he is trying to please the operators.

At the opening of the discussion, replying to a question from President Warner, Mr. Lott said that the instructions are that, if one pilot seems habitually to lean heavily on the throttle, excessive engine-speeds show up soon because the performances each day are comparative. Several airplanes fly over the same course each day, and the officials soon learn that one pilot seems to operate at higher speeds than do the other pilots. When the other pilots call this to his attention, he will change his tactics before the figures are available to the officials.

At the conclusion of the voluminous discussion, Mr. Lott said that his company is very well satisfied with the propeller it uses. At full throttle, he remarked, the propeller runs in the air at 1740 to 1750 r.p.m. The radial engines are set to run at 1900 r.p.m. at full throttle and the planes cruise at about 1640 r.p.m. When a new propeller is available it is tested and, if it seems to give better performance than the previous ones, the company is inclined to try out more of them.

Banquet Appeal Irresistible

Sir Hubert Wilkins Sketches Polar Flights; L. M. Woolson Describes Diesel Aircraft-Engine

CARL B. FRITSCHE, president of the Aircraft Development Corp., Detroit, was Toastmaster at the Aircraft Banquet held in the grand ballroom of the Book-Cadillac Hotel on Tuesday evening, April 8. He was introduced by Robert Insley, vice-chairman of the Aeronautic Division of the Detroit Section, which sponsored this memorable occasion. The paper presented was entitled The Packard Diesel Aircraft-Engine and was delivered by L. M. Woolson, its author, aeronautical and research engineer for the Packard Motor Car Co., Detroit; it was printed in full in the April issue of the S.A.E. JOURNAL, beginning on p. 431.

Before introducing Captain Woolson, Chairman Fritsche remarked that Col. J. G. Vincent was one of three engineers who had the most to do with the celebrated Liberty aircraft-engine during the War and that one of the interesting side-lights relating to it is the fact that some of the old-time night airplane-pilots, who operate on an air line which uses radial air-cooled engines but also has some of the old Liberty engines still in service in Douglas airplanes, feel safer when flying over the Alleghanies with an old Liberty-engine powerplant than when the airplane is powered by a modern radial air-cooled engine.

The names of a few of the men in the Packard organization who were helpful to Captain Woolson in this enterprise were then called by Chairman Fritsche and, as these gentlemen arose, they were greeted with applause.

The art of flight is becoming less mysterious each day, Chairman Fritsche continued, but the three obstacles personified as Old Man Gravity, Old Man Weather and Old Man Premature Combustion, still exist. If we cannot change the laws governing the forces of Nature, the best thing we can do is to balance one force against another to serve the needs of mankind. Captain Woolson proposes to tell us how to kill Old Man Premature Combustion, particularly if the landing-spot is not safe from the standpoint of a plane that is fully loaded, and especially when using fuel of high volatility. The paper was then presented.

Surprising demonstrations were made by Captain Woolson to prove the reluctance of the fuel used to ignite except when atomized, such as throwing lighted matches into it and the like. In conclusion, motion pictures illustrated two mechanics dismantling the engine completely; they accomplished this work in 17 min., according to Captain Woolson. The pictures included also views of the company's plant.

Following his paper Captain Woolson answered a few written questions relating to low operating-costs when using fuel oil in Diesel-engine operation, to oil consumption and the like.

Gayety Pervades Banquet

Notable, indeed, was the splendid appearance of the banquet hall. Ten-place tables decked with snowy linen and graced with flowers filled it completely, and those of the more than 725 members and guests present who had been dilatory in reserving places must perforce seek seats at similar 10-place tables located in adjoining rooms and alcoves. Orchestral music lent added charm to the event and stimulated the already vivacious spirit of the diners.

The speaker's table was dignified by the presence of numerous celebrated persons. Seated thereat were:

Carl B. Fritsche, Toastmaster; vice-president of the Detroit Aircraft Corp.

L. M. Woolson, aeronautical and research engineer, Packard Motor Car Co., Detroit

Edward P. Warner, President of the Society and editor of *Aviation*, New York City

Miss Amelia Earhart, assistant general traffic manager for the Transcontinental Air Transport Co., New York City

Sir Hubert Wilkins, Arctic and Antarctic explorer

Hon. Clarence M. Young, Assistant Secretary of Commerce for Aeronautics, Aeronautics Branch, Department of Commerce, City of Washington

Dr. George W. Lewis, director of aeronautical research for the National Advisory Committee for Aeronautics, City of Washington

Alvan Macauley, president of the Packard Motor Car Co., Detroit

William B. Mayo, chief engineer of the Ford Motor Co., Dearborn, Mich.

Ray Cooper, manager of the All-American Aircraft Show, Detroit

L. Clayton Hill, Chairman of the Detroit Section, and vice-president, Dietrich, Inc., Detroit

Robert Insley, Chairman of the Aeronautic Division of the Detroit Section and vice-president of the Continental Aircraft Engine Co., Detroit

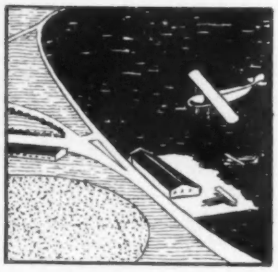
P. Altman, Chairman of the Meetings Committee of the Detroit Section and professor of aeronautical engineering, University of Detroit

PROMINENT PERSONAGES AT THE AIRCRAFT BANQUET

Carl B. Fritsche (Upper Left), Toastmaster, President of the Aircraft Development Corp.; L. M. Woolson (Upper Right), Who Presented the Paper Entitled, The Packard Diesel Aircraft-Engine; Sir Hubert Wilkins (Lower Left), Arctic and Antarctic Explorer, Who Delivered an Address; and Miss Amelia Earhart (Lower Right), Assistant General Traffic Manager for the Transcontinental Air Transport Co.

Intense interest was manifest while Sir Hubert delivered the following address:

Address by Sir Hubert Wilkins



I can think of only two reasons why I should speak this evening to the members of the Society of Automotive Engineers. Perhaps one is because I find I shall not be able to commute back to the South Pole until next year; so, I shall be forced to stay on this thawed-out soil for a few months and, possibly, to use one or another of your products. Of course, which one I shall use will depend on which manufacturer can be most generous to an importunate explorer. The other reason is because I realize, as you realize, that those of us who set out to do work and to use engines under such dangerous conditions as exist in the North and the South Pole regions must conclude that we are very much indebted to the automotive engineer for the development of the aircraft engine to its present state of perfection.

It was only with that knowledge of the dependability of aircraft engines, brought out through scientific research in the automotive industry, that we could set out with confidence to do the work that was needed in the North Pole and the South Pole regions. Without that confidence it would have been impossible for me to come to Detroit four years ago and ask for the sympathy and support of the Detroit Aviation Society. We expected to carry out that work, but it was not merely an adventure or a trip for excitement or pleasure; it was because that work had to be done before we could progress with other branches of science. We believed that, with airplane engines and with aircraft, we could carry out that work speedily and economically.

It was only with the confidence that we had in the dependability of aircraft engines that I could set out with my late companion Carl B. Eielson, to fly over those 2200 miles between Alaska and Spitzbergen, 2200 miles between land points, flying over ice on which Amundsen, Byrd and others said it would be impossible to make a landing. We proved that it was possible to make a landing, because we landed three times on Arctic ice, and took-off from it again. But there was a possibility that, after we left Point Barrow, we would not find one safe landing-spot; at least, we were certain that we could not continue to fly our plane to Spitzbergen if we made a landing, and so we depended on our engine.

Antarctic Experiences Related

Having completed in that flight the main program of the work in the Arctic, we were prepared to set out on our journey to the Antarctic. It had been said by everyone who had been in the Antarctic previous to our visit, that it would be impossible to fly airplanes in those regions because of high wind-velocities, the uncertainty of the surface conditions that we would meet, and because of low temperatures. We proved in our Arctic flights that temperatures did not necessarily obstruct engine operation; at least we assumed that we could protect the engines from such low temperatures and have them give us good service.

So we went into the Antarctic with confidence, depending only on our engine, taking with us our pilots D. Cramer and Al. Cheesman. We were confident that we could put our airplane on the back of a little steamer just 110 ft. long, take it out 350 miles from the shore, put it over the side on water that was 2000 fathoms deep, and start out on an unbroken flight of 400 miles during which there was not one possible chance of a safe landing. Had we been forced down in any mile of our flights in the Antarctic this year, there was no possibility of landing safely; and if, by a miracle, we could have landed safely, there was no possibility of rescue. We were fortunate to be able to get through with success, although for the last three years we have never had any great difficulty with our aircraft engines in operating them either in the Arctic or Antarctic.

For Polar work, we must have not only engine dependability but also fuel economy. I feel sure that, in the Diesel aircraft-engine development described by Capt. L. M. Woolson this evening, the entire automotive industry and all of the scientific representatives of this great Country of America and the world in general will owe a great debt to him and to his associates for having developed an engine that we expect and know will be dependable and at the same time be economical. This wonderful new product will help air transportation in this Country, and also will help substantially those of us who must do our work in fields much farther from Detroit than is the Municipal Airport which we had the extreme good fortune to visit today.

We have had some exciting adventures; some trying times. But we realize that it has been a satisfaction to those of my friends who have been watching my work for four or five years, that we have now completed, in the Arctic and in the Antarctic, the general plan of operation with airplanes. That has brought us to another stage of exploration of which I hope you will hear something more next year.

It has been a great pleasure to have visited the Detroit Aircraft Show and to see the remarkable improvements that are taking place in the design of airplanes and in the application of engines. It is perhaps my greatest pleasure since returning from the Antarctic about 10 days ago to accept this invitation of your Society to be present tonight and to hear Captain Woolson's paper.

Weight Reduction and Safety

Worth of Airplane Lightness and Tanager Safety-Features Stated at Aircraft-Session

TWO papers, both of which dealt with very timely subjects, according to Chairman Charles J. McCarthy, were presented at the Aircraft Session held Wednesday morning, April 9. The one which described the development of a safe airplane was delivered by T. P. Wright, chief engineer of the airplane division, Curtiss Aeroplane & Motor Co., Inc., Garden City, N. Y., as exemplified by the Curtiss Tanager. The second paper, entitled What Is Lightness Worth in an Airplane?, was presented by Edward P. Warner, president of the Society and editor of *Aviation*.

Curtiss Tanager Development Outlined

In May, 1927, the Daniel Guggenheim Fund for the Promotion of Aeronautics announced its Safe-Aircraft Competition, and on Jan. 1, 1930, the first prize in that Competition was awarded the Curtiss Tanager airplane that had been entered by the Curtiss Aeroplane & Motor Co., Inc. What transpired in the intervening 31 months was revealed in the paper by T. P. Wright, which deals with the research, design and development work of the Curtiss engineers. The paper is printed in full in this issue beginning on p. 543.

In the discussion which followed, after lantern-slide views were shown by Mr. Wright, J. T. Hartson of the Comet Engineering Co., Madison, Wis., asked how steep a dive the plane will make when the power is cut off and the elevators are pulled back suddenly; that is, in a stalling position, how steep a dive the airplane makes while obtaining flying speed again, and whether the

plane "squashes" out of it or puts its nose down. Mr. Wright said that the plane puts its nose down slightly.

One of the competition tests, Mr. Wright said, was the requirement that the plane recover within 250 ft. from any maneuver or any attitude in which it would be placed, by the use of controls; or, within 500 ft., automatically, without resorting to controls. Describing the way in which the test was carried out, he remarked that the plane, from a fairly high speed, was pulled up into almost vertical stalling attitude; then the rudder was kicked hard over and the controls were released, which let the plane fall off in the direction that the rudder indicated. He thought that the actual speed could not have been more than about 60 m.p.h. to recover in 500 ft., as was done.

Replying to M. B. Farr, of the Metallurgical Laboratories, Philadelphia, Mr. Wright said that the landing-gear was entirely conventional. The only special feature was the increased oleo stroke, which was approximately double the usual practice. The arbitrary increase in the load factors which were used in this design was, in Mr. Wright's judgment, about 8 instead of about 6, which was necessitated by the more rapid vertical descent of the airplane than is common practice. This airplane hits the ground at a velocity about half again as high as do normal airplanes, he remarked.

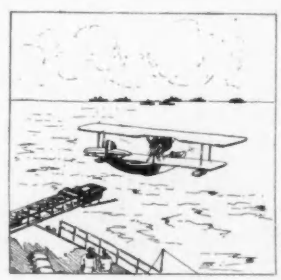
Ralph Upson asked for more detail as to the procedure and action in making what is, for this plane, apparently a normal turn with the ailerons. Mr. Wright replied that, so far as going into a bank is concerned, no rudder is necessary. The stick can be thrown over to any amount to give the turning movement. The plane will then automatically take the correct angle, so that there will be no skipping or skidding, leaving the rudder absolutely neutral.

CHAIRMAN AND SPEAKERS AT THE AIRCRAFT SESSION

C. J. McCarthy (Center), of the Chance Vought Corp., Chairman; President Edward P. Warner (Left), Editor of *Aviation*, Whose Paper Was Entitled "What Is Lightness Worth in an Airplane?"; and T. P. Wright (Right), of the Curtiss Aeroplane & Motor Co., Who Presented the Paper on Construction Details of the Curtiss "Tanager"

Fear Must Be Overcome

President Edward P. Warner stated that the problem of flying, as he sees it, is not the coordination of control. That is an old story. In a sense it does not exist in any other vehicle, but it does exist in many other daily activities. Anyone who plays golf knows how to coordinate his muscles, he continued, or else he does not hit the ball; and if we can get all of the golfers to flying airplanes, we will have a good business. In golf, if you do not coordinate, you miss the ball, but if you do not coordinate when flying an airplane something worse will happen.



It is the mental fear of some dire consequence of improper coordination that we are concerned with, President Warner remarked. When we produce an airplane in which one can coordinate properly or improperly, or badly or not at all, and still not get into serious trouble, the difficulty of flying an airplane will have been very largely diminished if not almost entirely eliminated; but we will still try to coordinate properly.

Worth of Lightening Airplanes Analyzed

President Warner's paper formed the the second part of a trilogy. The first, entitled The Economic Speed-Weight Relation in Air Transportation[1], concerned with the relation between speed of flight and the costs of air transportation, was presented at the Aeronautic Meeting held at Cleveland in August, 1929. "I hope to have the opportunity of presenting the third before some future meeting of the Society," the author said.

The general purpose is the economic analysis of certain elements entering into air transport, the speaker continued, and the substitution of definite computation for guesswork upon such questions as: How fast can we afford to fly? The objective of the moment is fixed upon the determination of the permissible degree of refinement in an airplane structure. How much is lightness worth? The question is one upon which many engineers have formed their own opinions. Their conclusions range in written expression from the epigrammatic observation of Major Green, of the British Armstrong-Siddeley Co.—that he would "spend a pound to save a pound, any time"—to an estimate of $40 per lb. offered by a well-known American metallurgist.

Certain hypotheses must be accepted as a preliminary to such an analysis, President Warner remarked. It must be assumed for instance, that there is an infinite range of powerplants available, and that one exactly fitted to the conditions of the problem will always be selected. Actually, if a weight saving makes it possible to reduce the engine output by 2.4 hp., instead of adopting a new engine with that much less power, the user of the plane will either increase the cruising speed slightly or cruise at a fractionally lower proportion of the rated power-output. Nevertheless, the assumption is fair, for it correctly represents the general average effect and, when the changes of required power are substantial, it becomes possible to shift over to an engine of lower power than the one used with the original, and heavier, structure.

As a measure of arithmetical convenience, unit weight-savings are of course assumed in the computations given in the paper, the author said. Therefore, the changes in power and in costs will appear exceedingly small; but, in practice, any definite refinement introduced into construction, at a de-

[1] See S.A.E. JOURNAL, December, 1929, p. 635.

finitely recognized increase of cost, is likely to save considerably more than a single pound and the derived figures will be multiplied correspondingly.

Disposition of Weight Saved Discussed

In approaching the problem, President Warner stated that two alternative assumptions upon the disposition to be made of weight saved, so distinct that they would have to be treated as separate cases, are available. If a pound be saved in the structure or the engine, he continued, that reduction can either be used to permit a general decrease in the size of the airplane, scaling down the engine power, the wing area and the weight of the remaining structure all in the same ratio, or the power and dimensions may be kept unchanged and the pound so saved may be considered as added to the permissible payload.

Palpably, said President Warner, the first hypothesis is the more tenable and it will be used. There will not, by virtue of the mere fact of improved structural design and lessened weight, be created an increased traffic. The presumption is that a plane, or a number of planes, of great enough total capacity to handle all the available traffic, will in any case be used by an air line. To increase the allowable payload of the individual craft serves only on the one hand to reduce the average percentage of full load carried and, on the other hand, to reduce somewhat the number of occasions upon which second sections will have to be run.

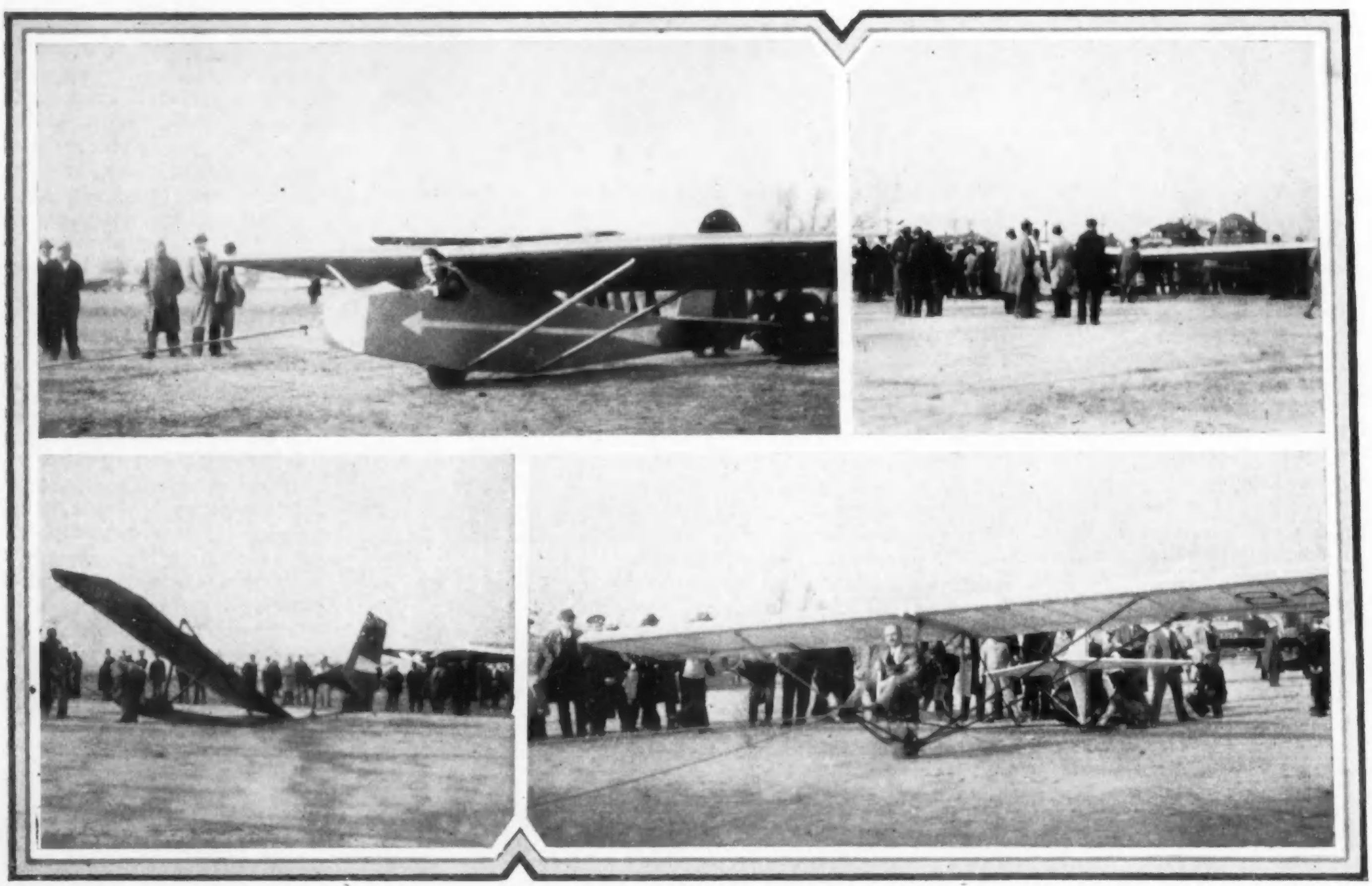
President Warner then presented his statistical raw material. So far as possible, in setting up formulas for cost and performance, he followed the forms developed and applied in his earlier paper[2].

In conclusion, President Warner said that the results of this particular analysis have left us within, and, in fact, near the middle point of the rather wide range covered by speculation and estimate in the past. Nevertheless, whatever the magnitude of the figures that individual engineers may have set up as representing what the presumed value of weight-saving is, few of them, especially among commercial builders in the United States, have had the courage of their convictions or have been prepared to shape their courses in accordance with their own estimates. The same criticism holds for the operators.

Points regarding the use of light-weight metals were brought out by W. G. Harvey, of the Aluminum Co. of America, Cleveland, in the discussion following President Warner's paper. These were concerned with some of the newer high-strength aluminum-alloys and, possibly, beryllium, as well as other light-weight materials that are coming into commercial use, such as the magnesium alloys which, he said, are certainly no longer experimental. A. F. Winn, of the Skelly Oil Co., said that safety is an added feature of incentive toward saving of weight, because it is his belief that a smaller airplane is somewhat safer than a larger one.

A. W. Winston, of the Dow Chemical Co., Midland, Mich., added to Mr. Harvey's remarks in regard to magnesium and said that his own company's work parallels that of Mr. Harvey. He stated also that the result of the work in connection with fabricated forms and production of standard shapes is proceeding rapidly enough so that he feels that the day is not far distant when it will be possible to secure tubing rods, and sheet in quantities sufficient to take care of any needs that may arise; further, that the prices for this material

[2] See S.A.E. JOURNAL, December, 1929, p. 635.



S.A.E. MEMBERS CAUGHT OUT ON A FLY

President Edward P. Warner (Upper Left), and A. J. Underwood (Lower Right), Director of Society's Aeronautic Activities, Who Essayed Glider Flights. Spectators Who Witnessed These and Other Glider Demonstrations Are Shown Respectively in the Lower Left and Upper Right Views

will not be excessive but will be at such a figure that magnesium will be attractive to practically all progressive aircraft designers.

President Warner replied to several direct questions and said also that, for example, to save 1 lb. on a set of wrenches or other accessories that are carried in an airplane—as was suggested by J. Arthur Thompson, of Gladacres, Inc., Rushville, Ill.—is worth almost as much as to take 1 lb. out of the airplane structure; in fact, it may be worth somewhat more, with the method of analysis that President Warner had used. Any pilot who was engaged in airplane pursuit-operations in France in 1918, he continued, would have answered, if asked, that there were times not infrequent when the increase of performance that would have resulted from a little saving in weight of structure would have been worth all of the money in the world.

Unique Glider Session Held

Glider-Design Fundamentals Stated and Adult Supervision of Glider Construction Advised

THE Principles of Glider Design were stated by William J. Perfield, engineer of the Stout Engineering Laboratories, Inc., Detroit, at the glider session held Wednesday afternoon, April 9. P. Altman, professor of aeronautical engineering, University of Detroit, was chairman and more than 75 members and guests were in attendance.

Before introducing Mr. Perfield, Professor Altman gave a general outline of the revival of the glider movement in this Country. He remarked that he used the word "revival" because some of the earliest pioneers in aviation determined all of their experimental data from the use of gliders, and used the information later in the development of powered airplanes. The revival began in Germany shortly after the Armstice was signed. Because of limitations set upon German aviation thereby, the Germans turned to the development of gliders and have had remarkable success.

Professor Altman said also that, in this Country, the revival of interest in gliders was largely due to E. S. Evans, who organized the Evans Gliders Club of America in 1928. The name was changed to be the Nationad Glider Association, briefly known as the N. G. A. because of the National interest shown in this movement. This Association has been responsible for the majority of the glider contests that have been staged in the United States. William B. Mayo, chief engineer of the Ford Motor Co., is now president of the Association.

Continuing, Professor Altman said that the glider is essentially an airplane without an engine. The controls, surfaces, wing and fuselage design are exactly similar to airplane construction and the method of bracing is also the same.

Glider Design Analyzed

Mr. Perfield said in effect that those who have had the good fortune to fly in a glider have been greatly impressed by the experience. Even veteran airplane pilots are enthusiastic about the thrill of gliding. It has struck the fancy of American youth and, just as the perfection of the automobile changed Dobbins's harness to a saddle and the development of power boats relegated the sailboat almost entirely to sporting pursuits, it now appears that the advent of the airplane is to establish gliding as a sport.

The practical value of gliding to modern aviation is much debated, Mr. Perfield continued, and said further that gliding is certainly in some respects an asset to the aeronautic industry; but the point of greater concern at the moment is the distressing liability it may become if not properly directed. Glider Clubs are springing up all over the Country. Young men and young women by the thousands are eagerly grasping this opportunity of getting into the air, economically, and, we hope, safely. Many commercial gliders are being sold but, more often, the ships are privately built. High-school stuents and young working men with no knowledge of aircraft structures and flight loads are working from incomplete blueprints and cheap-magazine plans. Materials of questionable quality are often substituted when specifications cannot be met.

WILLIAM J. PERFIELD

Author of the Paper on the Principles of Glider Design, Presented at the Glider Session. Mr. Perfield Is Connected with the Stout Engineering Laboratories

PROF. P. ALTMAN, CHAIRMAN AT THE GLIDER SESSION

Professor Altman, of the University of Detroit, Stressed the Necessity for Adult Supervision of Glider Construction

Such conditions, said Mr. Perfield, are sure to spell disaster sooner or later, especially with the present tendency toward automobile towing which increases the normal flying altitude from 30 to 40 ft. to as high as 800 ft. The aeronautic engineer more than any other individual is qualified to check this alarming situation. Whether or not he is interested in personal participation in the sport, he is in a position to do the industry at large a great service by making his technical knowledge and experience available to the amateur glider enthusiast in the interests of safety.

Gliders in Action Thrill Crowd

NUMEROUS members and guests visited the Detroit Municipal Airport on Wednesday afternoon, April 9. Conveyance was by motorcoach from the Book-Cadillac Hotel. The occasion was a demonstration of glider flying made under the auspices of the National Glider Association. Shock-cord-

(*Continued on p.* 649)

Chronicle and Comment

Woolson a Sacrifice to Progress

Mechanical progress of the race exacts a heavy toll of human life, energy and health. It seems inevitable that a certain number of men must be sacrificed that the multitude may gain in efficiency, comfort and safety. The passing of Capt. L. M. Woolson late in April while engaged in another long-distance test flight with a Diesel-engined airplane brings keenly home to everyone this unfortunate phase of our mechanized age. In the search for greater safety, efficiency and economy in aviation, Captain Woolson went to his own untimely death, bringing to an end a most brilliant engineering career.

The whole automotive industry must deeply mourn the loss of such a man, the newspaper reports of which came with particularly shocking suddenness to the members who attended the Aircraft Banquet at the Society's Aeronautic Meeting in Detroit on April 8 and heard Captain Woolson deliver his paper in which he gave the details of the engine which signalized the crowning success of his life. Clarence D. Chamberlin voiced the sentiment of all his colleagues when he said at Albany, upon hearing of the disaster,

> Aviation has lost one of the greatest research engineers and a man to whom the entire industry looked for the solution of at least a major portion of the present troubles with powerplants.

An account of Captain Woolson's career and principal achievements in the line of endeavor to which he had devoted the last half of his very busy life is given in this issue of THE JOURNAL on page 651.

Inspection Trips as a Drawing Card

PROBABLY every Section that has arranged an inspection trip as a feature of one or more of its monthly meetings has been gratified by the large attendance and the enthusiasm displayed. As examples, the February, March and April plant-inspection meetings of the Milwaukee Section resulted in probably the largest turn-out of members the Section has ever had.

Similarly, the March and April inspection trips and technical sessions of the Northern California Section brought out unusually large numbers of members. The Metropolitan Section service-stations meeting in March drew about 200 members, and the Pennsylvania Section's trip last October to the Elizabeth, N. J., oil refinery was attended by about 300 members of that Section and the Metropolitan Section.

The almost invariable success of such meetings offers a suggestion to Section officers who will be elected this spring and upon whom will devolve the duty of arranging schedules and programs of next season's meetings.

Inspection trips through large modern industrial plants are both instructive and interesting and lend special zest to technical papers presented by engineers of the plants visited. They also serve to get the members out of the particular rut of their individual work, giving them new ideas and stimulating their enthusiasm in their jobs and in the Section meetings.

Why Automobiles Are Artistic

THOUGHTS that automobile designers may advisedly mull over for a long time were expressed by Raymond M. Hood, an eminent architect, at the Detroit Section Body Division meeting in March when he said:

> The real path that leads to beauty is the path of utility. . . . The art of automobile design is one of the highest arts in the world. . . . because you have tackled your problems so sincerely and so simply. . . . You have unconsciously developed a marvelous car from the point of view of utility, and beauty has come along with it. . . .
>
> You will find that in making sacrifices to the mistress of beauty we wind up with an overdressed, vulgar, sort of frowsy old frump. . . . The danger is that the automobile is going to be overdone.

Mr. Hood's warning is timely in this day of extremes and mass follow-the-vogue tendency, when the bizarre, the grotesque, the striking is regarded as "modern" and the art of the past is considered passé. True art is a matter of proportion and relation of lines, of harmony of colors and proportion of color values, and of suitability of design to the utility of an article. Fortunately, the designs that are most suitable as regards utility, efficiency and comfort are also most artistic. Taste in style varies from period to period because of mass psychology but true art appreciation is constant over the centuries.

The "horseless carriage" design of 30 years ago was inappropriate to a mechanically propelled vehicle of 10 times horse speed, hence the ridiculous appearance of those early vehicles. Panhard forgot horse-drawn vehicles, started with a clean sheet and produced the arrangement of parts, each best for its purpose, that has become almost universal today. Out of this arrangement has developed the practical, comfortable, fast and handsome motor-car of today.

Standards Committee Division Reports

THIS number of the S. A. E. JOURNAL is comprised of two sections, Section 2, which contains the reports prepared by the Divisions of the Standards Committee since the Annual Meeting last January, being inserted separately after Section 1, the regular issue, was bound. These reports will be presented for approval by the Standards Committee at its meeting on Sunday afternoon, May 25, and to the Council and the members at the Summer Meeting at French Lick the last week of this month.

The reports have been considered carefully by the respective Divisions and given as much publicity as possible. They are believed to be in acceptable form. Any proposals for changes should be only for important reasons.

Should Section 2 be missing from this copy of THE JOURNAL when received, a prompt request addressed to the Standards Department of the Society will bring a copy by return mail.

Development of a Safe Airplane—the Curtiss Tanager

By T. P. Wright[1]

Detroit Aeronautic Meeting Paper *Illustrated with* Photographs and Charts

In May, 1927, the Daniel Guggenheim Fund for the Promotion of Aeronautics announced its Safe-Aircraft Competition, and on Jan. 1, 1930, the first prize in that Competition was awarded the Curtiss Tanager airplane that had been entered by the Curtiss Aeroplane & Motor Co., Inc. What transpired in the intervening 31 months is revealed in the paper, which deals with the research, design and development work of the Curtiss engineers.

The theoretical calculations that were first made showed that no existing airplane could possibly meet the rules and that the speed range could be met by using slots and flaps in conjunction with a good basic section. The work done in the wind-tunnels to determine the most advantageous design of slots and flaps and their specific application to a medium high-lift wing-section, the Curtiss C-72, is described. This resulted in a combination of front and rear slots and a floating aileron.

Considerations of necessarily large wing-area accompanied by small unit-weight dictated the selection of a biplane wing-arrangement with an overhung upper panel. Resistance and practicability eliminated the open cockpit in favor of a cabin fuselage with bulged sides that faired in well with the radial air-cooled engine, the Curtiss Challenger, that was selected as the powerplant. Landing-gear and tail-skid design received very careful consideration that resulted in the choice of a large-stroke oleo shock-absorber for both. The slot mounting, flap control and floating-aileron control were the most interesting features from a mechanism-design standpoint and these are described. No new types of construction were developed in the design of the structure, although every part was refined to the limit to save weight.

Data on the types of construction and the materials used are presented, with numerous illustrations of the various units. Emphasis naturally is placed on the safety features of the airplane, such as slow speed of flight, slight likelihood of striking the ground in any but a normal attitude, freedom from any tendency to fall off to one side when in stalled flight, inability of experienced pilots to make the airplane spin, a steep angle of climb and the elimination of using the rudder for normal flying and turning maneuvers.

A brief description of the flight tests made by the company's pilots between Oct. 12 and 29, 1929, is given. In these tests the only changes made were lengthening the stabilizer-adjustment screw and modifying the cowling and propeller, these being done to secure a slightly more favorable performance. The tests conducted by the Guggenheim Fund pilots were divided into three groups—qualifying, safety and Competition rating tests—all of which were satisfactorily passed by this airplane alone.

Although in the last ten years aviation has made rapid advance in technical development and has realized a substantial position in the consciousness of the general public, nevertheless, complete acceptance of the air as a continuously satisfactory lane of travel, in competition with the earth or water, has not been attained despite the statements of aviation enthusiasts to the contrary.

Some controversy exists as to whether fear or fare represents the more important deterrent, and very recent events connected with the increased traffic over air-transport lines immediately following drastic rate reductions have lent plausibility to the arguments of the proponents of fare reduction as the chief item of importance in selling aviation to the general public. Nevertheless, the belief held by many is that the greatest single advance in aviation will have been made when air transportation can definitely be shown to be safe, so that the great bogey, fear, can be removed from the consciousness of the passenger before, during and after making a trip by airplane.

Engineers and inventors have constantly sought new means of making airplanes safer and more foolproof, yet the progress has, in general, been very slow. About three years ago a study was undertaken by certain designers to find out exactly what element in present-day flight constitutes the greatest hazard. In general this study revealed that certain airplane characteristics require radical change before real safety will obtain when a particular airplane is being flown by the average man. These characteristics are: reduction in landing speed, improvement in control at stalling speed, realization of complete automatic stability, removal of the incipient spinning tendency of the airplane and reduction of take-off distance and landing run, accompanied by improved angle of climb for obstacle clearing. The feeling was that, if all airplanes could be improved in these characteristics, a 60 to 90-per cent reduction in airplane accidents coming within that most prevalent class, improper judgment of pilot, would immediately follow. In short, the airplane must be made as nearly foolproof as possible.

Guggenheim Safe-Aircraft Competition Inaugurated

The next problem was to set down quantitatively the values for the characteristics listed above, which, if attained, would represent a sufficiently substantial improvement in performance to permit the airplane possessing these qualities to be truthfully described as a safe airplane. This service was admirably performed by

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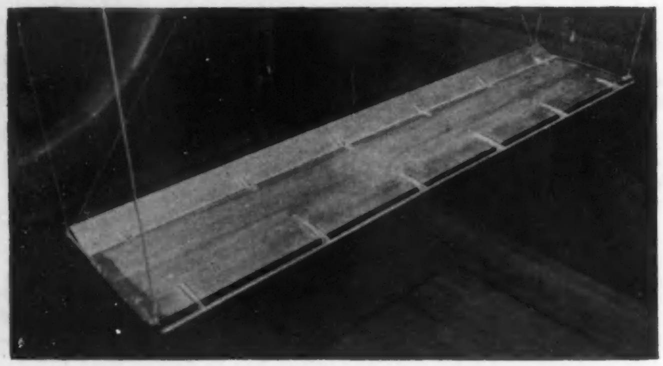


FIG. 1—THE C-72 SLOTTED WING

This Was Used in Developing the Most Advantageous Slotted Flap and Its Optimum Angles Both When Acting Alone and in Conjunction with the Leading-Slot Edge, 319 Tests Being Made To Establish Values of Lift, Drag and Pitching Moment

the Daniel Guggenheim Fund for the Promotion of Aeronautics. In May, 1927, the Fund distributed its announcement of the Safe-Aircraft Competition, in which a generalized statement of purpose and a specific description of competition detail requirements were made public. I feel that this paper would be incomplete without quoting the finely worded opening paragraphs of the announcement:

> The average man's attitude toward air travel today is still very skeptical. He is interested in reading of flying exploits and glad when his Country's airmen set new records and probably regards with mild resentment the reported superior aeronautical progress of other nations. But in the back of his head lurks a deep-seated reluctance to trust the most elusive of the elements, the air. The fury of tornadoes ashore or typhoons at sea for some reason holds less terror for him than the paradoxical business of defying gravity with heavier-than-air machines. He may send his letters by Air Mail but he prefers to let some one else do the flying.
>
> The Daniel Guggenheim Fund for the Promotion of Aeronautics has recognized from the outset that any effort to make air traffic an integral part of our national commercial life must first reduce and as nearly as possible entirely overcome the popular skepticism of air transportation. In meeting this problem the Fund has dealt frankly with aeronautic development as it stands today and, far from glossing over the fact that air travel is still attended by some risks, it has regarded those risks as one of the fundamental reasons for its own existence. The very first of its four general purposes is to promote aeronautic education, both academic and general, and thereby to acquaint the public at large with the remarkable advances man has achieved in conquering the air and the astonishing degree of safety he has already attained.
>
> As a fundamental step in its educational program, the Fund has planned and is hereby announcing a Safe-Aircraft Competition by which it hopes not only to demonstrate that airplane travel is basically as safe as railway and steamship travel, but also to stimulate scientific investigation and practical invention into evolving new devices and principles whereby air travel will convert even the most confirmed skeptics and will take its place in our lives as the fleetest, cleanest and safest of the three recognized modes of travel today.
>
> The Daniel Guggenheim Safe-Aircraft Competition has been prompted by a conviction of the necessity and feasibility of aerodynamic safety. Its object is to achieve a real advance in the safety of flying through improvement in the aerodynamic characteristics of heavier-than-air craft, without sacrificing the good practical qualities of the present-day aircraft.

A careful study of the Competition requirements disclosed that rules were set down to define quantitatively airplane characteristics that, if realized, would most certainly make the airplane possessing them safe. The difficulty of attaining the characteristics was at once appreciated. We decided, however, almost at once to enter the Competition, and in October, 1927, decided upon and entered into an intensive program of research. This program was sufficiently advanced so that in April, 1928, actual design work on the airplane could be commenced. The design and development then proceeded in an orderly way, followed by construction, so that the airplane was completed and first took to the air on Oct. 12, 1929. The plane was delivered to the Fund for test on Oct. 29, 1929, and on Jan. 1, 1930, we were informed that the first prize in the Daniel Guggenheim Safe-Aircraft Competition had been awarded to the Curtiss Tanager.

Method of Attack

As our designers were in sympathy with the detail requirements of the Competition rules, as describing a truly safe airplane, we decided soon after the announce-

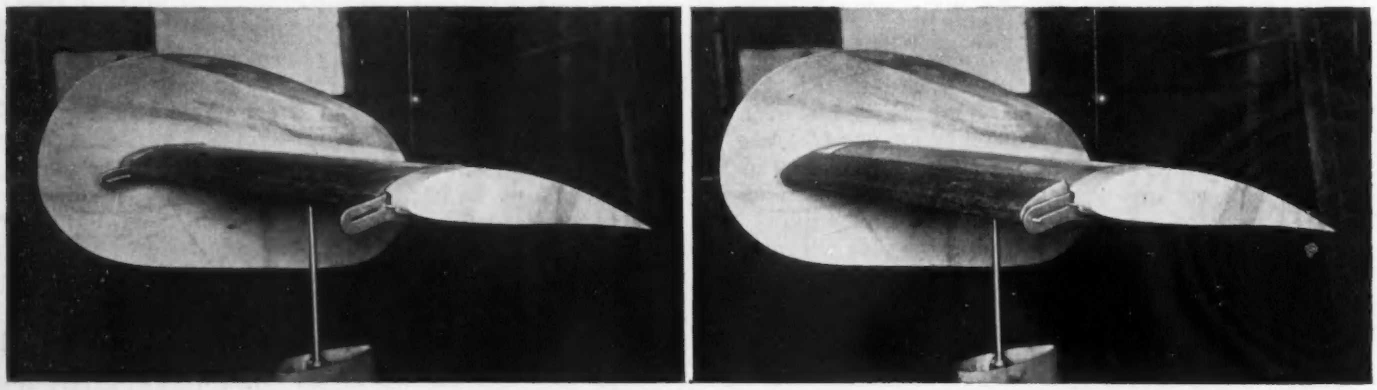


FIG. 2—THE TEST MODEL OF THE C-72 SLOTTED WING

This Was Used To Determine the Setting of the Auxiliary Airfoil with Particular Relation to Its Opening Automatically at a Predetermined Angle of Attack of the Main-Wing Airfoil. In One View the Front Flap Is Shown Closed and in the Other the Flap Is Open

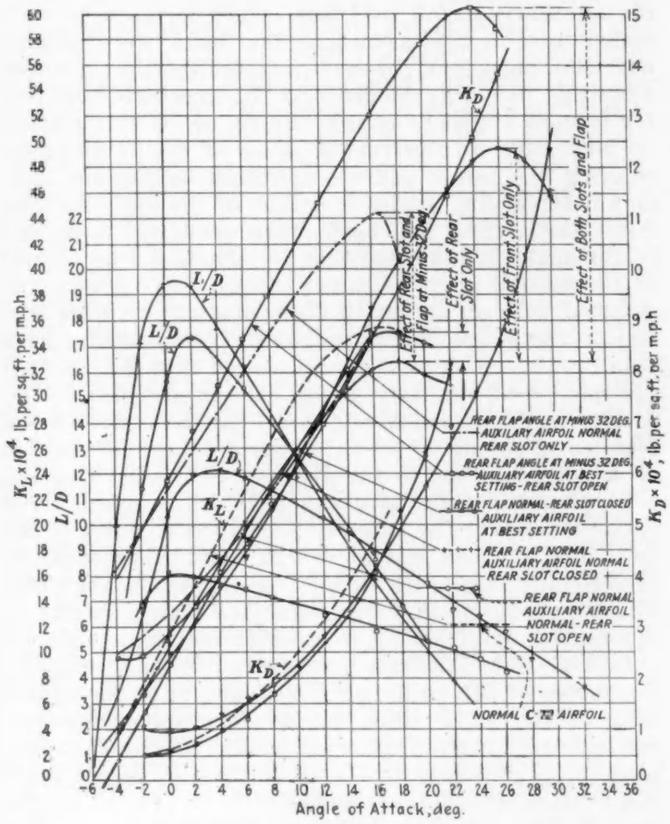


FIG. 3—CURVES OF LIFT, DRAG AND L/D RATIO OF THE SLOTTED WING SHOWN IN FIG. 1

ment was distributed to concentrate our efforts on a program of research and design leading directly toward the winning of the competition. This program included the following items:

(1) Theoretical calculations
(2) Wind-tunnel tests on (*a*) airfoils, (*b*) slots and flaps, (*c*) controls and (*d*) airplane models
(3) Design problems

A careful check by calculations showed that no existing airplane could possibly meet all the rules, and in fact only very few could pass any of the safety tests. The accuracy of this prediction was later demonstrated by the rapid elimination by the Fund's pilots of all stock or near-stock airplanes.

This study also showed the impracticability of realizing a sufficient gain by structural refinement and weight saving or improvement in streamlining alone to make possible the passing of the rigid requirements. Everything, therefore, pointed to the necessity of greatly improving airfoil characteristics, accompanied by improvement of controllability and stability. Quantitatively, the improvement required over existing airplanes was found to be 25 per cent for speed range, 75 per cent for lift coefficient, 50 per cent for stability and 50 to 100 per cent for controllability. Also, to live up to the spirit of the competition, these improvements must be accomplished without sacrificing the good practical qualities of the present-day aircraft. This was apparently aimed at the elimination of freaks.

These considerations and calculations, therefore, brought to us several concise problems requiring wind-tunnel research for their solution.

Wind-Tunnel Tests

A careful study was made of existing airfoils and of means for their improvement by auxiliary devices that had been described in technical literature. We concluded that the speed range required could just be met when using slots and flaps in conjunction with a good basic section, provided we could improve, to some extent, the characteristics reporting the results of previous investigators and provided the increase in lift made possible by the slots and flaps could be utilized over all of the wing area. This led us to the development of the wing-tip floating-aileron, a most important and necessary feature of the Tanager. Our study of basic airfoil-sections indicated that a section of medium high lift was required and we chose the Curtiss C-72 for the purpose.

This brought us to the second phase of the wind-tunnel research; namely, the most advantageous design of slots and flaps and their specific application to the C-72 section. The tunnel testing program that followed consumed about six months of steady effort and included the designing and construction of a special wind-tunnel balance, the conducting of more than 300 runs in connection with slot and flap settings, the testing of numerous auxiliary airfoil arrangements to obtain proper slot opening and pressure distribution and many special set-ups and tests to overcome routine difficulties as they arose.

The accompanying photographs illustrate the two types of airfoil model extensively employed. Fig. 1 shows the 10 x 50-in. airfoil model used in developing the most advantageous slotted flap, together with its optimum angles both when acting alone and when acting in conjunction with the leading-edge slot. The variables

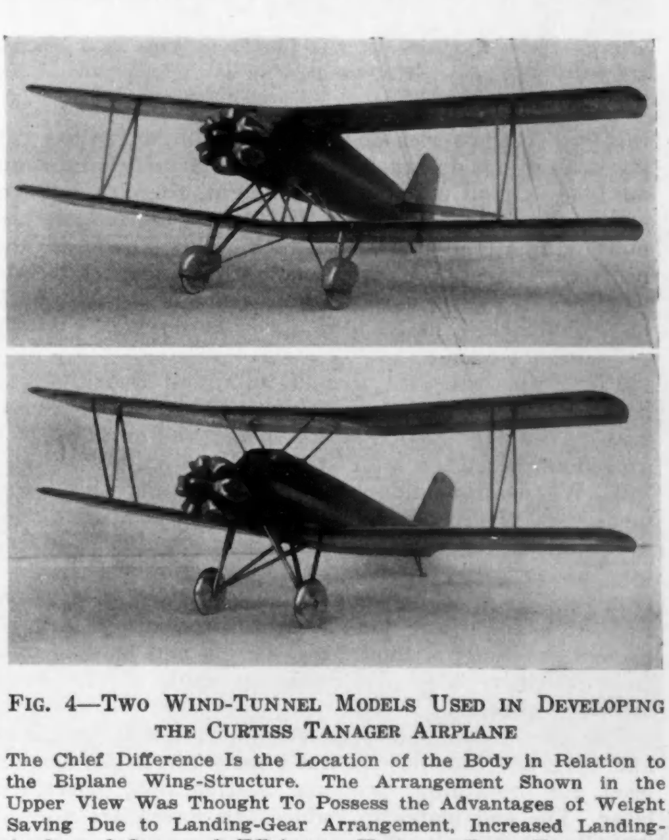


FIG. 4—TWO WIND-TUNNEL MODELS USED IN DEVELOPING THE CURTISS TANAGER AIRPLANE

The Chief Difference Is the Location of the Body in Relation to the Biplane Wing-Structure. The Arrangement Shown in the Upper View Was Thought To Possess the Advantages of Weight Saving Due to Landing-Gear Arrangement, Increased Landing-Angle and Improved Efficiency. However, Tests Showed That the Other Arrangement Actually Was Considerably Better

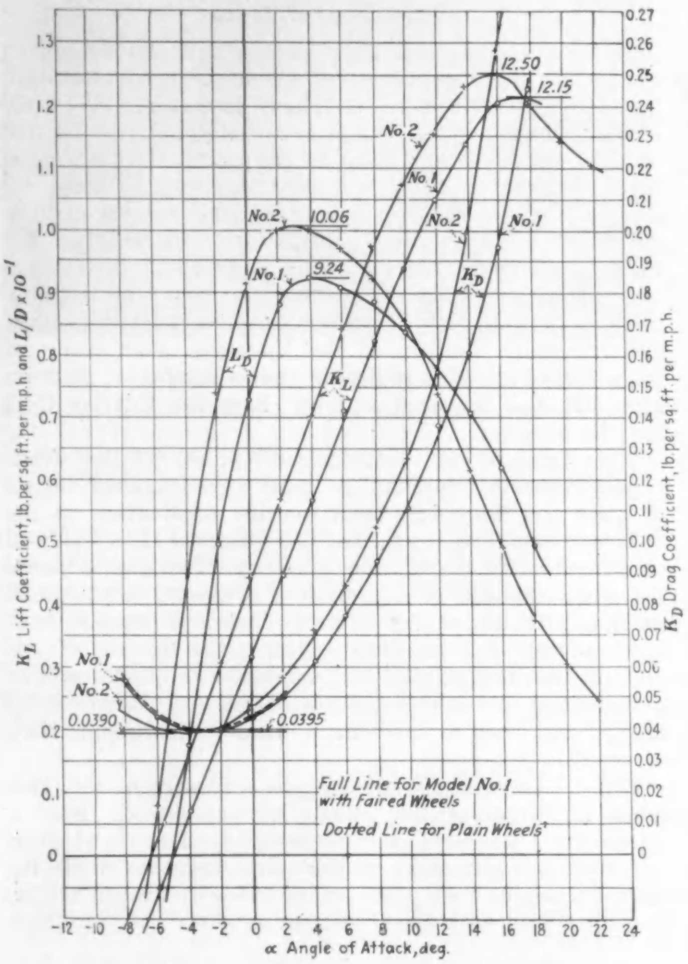


FIG. 5—TEST RESULTS ON THE LOWER OF THE TWO MODELS SHOWN IN FIG. 4

involved in the series of tests using this model are flap angle, rear-slot design, forward auxiliary-airfoil design, auxiliary-airfoil position as to height, forward location and angle with respect to the main wing-section and main-wing-airfoil angle of attack. Three hundred and nineteen separate tests were made to establish completely values of lift, drag and pitching moment for all possible combinations of these variables throughout the useful range of each.

Fig. 2 illustrates the 20 x 20-in. airfoil model used to determine accurately the setting of the auxiliary airfoil with particular relation to its opening automatically at a predetermined angle of attack of the main-wing airfoil. We desired and obtained an opening that commenced at 12 deg. and reached full-open position at 16-deg. angle of the wing. This range of opening is advantageous for the following reasons: The slot can be closed so that low drag and high L/D obtain for take-off run, high speed and maximum rate of climb; can be opened gradually without bang or jar and may become fully operative before the stalling angle of the main airfoil is reached.

The two views show the auxiliary airfoil in closed and open position but do not clearly show the system used for obtaining pressure distribution, described later. The end plates to reduce end losses are shown. A hollow brass chamber of accurate section, with 18 holes punched in its periphery, was built midway of the auxiliary airfoil and was connected thereto by a sealed tube to a manometer. The holes were covered with thin paper and the system tested for air-tightness. Then one hole was opened and the pressure measured for various angles of attack. By following this method we were able to construct a series of vector diagrams showing the forces and the resultant on the auxiliary airfoil at varying angles of attack of the main surface. After the setting had been determined which, by the vector analysis, indicated that the slot would be formed at the desired angle of attack, another model was constructed with an automatically operating auxiliary airfoil to check the values previously determined. As a result of the check test, we discovered that the old linkage method of auxiliary airfoil connection could not be satisfactorily applied in our case. This necessitated and resulted in the development of the rod-on-roller method of attachment used in the airplane as finally designed.

Another important development that had to be worked out in detail was the rear slot, located just ahead of the flap. The problem was to design a slot that could be permanently open with little or no accompanying drag. This we succeeded in doing, regarding it as a feature of the general development of considerable importance.

In Fig. 3 are illustrated, in the conventional manner, the curves of lift, drag and L/D found from the tunnel tests of the 10 x 50-in. model. The following summarizes the important items of note from these curves:

Basic Section	$K_y = 0.0033$
Basic Section Plus Rear Slot Open	$K_y = 0.0035$
Basic Section Plus Rear Slot Open Plus Rear Flap Down 32 Deg.	$K_y = 0.0044$
Basic Section Plus Rear Slot Open Plus Front Slot Open	$K_y = 0.00495$
Basic Section Plus Rear Slot Open Plus Rear Flap Down 32 Deg. Plus Front Slot Open	$K_y = 0.00605$

These figures prove an increase in the lift coefficient of 33 per cent due to the rear flap, of 50 per cent due to the front slot and of 83 per cent due to a combination of the two. The results are the more remarkable when the fact is considered that a relatively high-lift section is used as basic. Fig. 3 also shows the negligible drag increase of the rear slot, previously described.

Other tests conducted on airfoils included the determination of pitching moments and center-of-pressure travel for various combinations of slot and flap settings. The range of center-of-pressure travel was found to be from 27 per cent at a high angle of attack with the front slot open to 60 per cent with the flap alone operating. The movements are not excessive in comparison with those that obtain for normal airfoils, which are from 30 to 55 per cent of the chord.

The results of airfoil tests just described confirmed our belief that, from the standpoint of speed range and lift coefficient, an airplane could be designed to meet the competition requirements. The problem of control, particularly at the extremely slow speeds that would be used, remained to be solved. The research necessary to assure realization of adequate control centered around the ailerons, which, as previously mentioned, had been tentatively visualized as the wing-tip full-floating type.

Development of the Floating Aileron

Some of the considerations confronting us in developing the floating aileron were section, area, plan form, operating mechanism, general efficiency and freedom from flutter. The aerodynamic characteristics were de-

termined from a series of wind-tunnel tests that included hinge-moment tests to obtain proper balance, rolling-moment tests to obtain actual rolling-moments and, in addition, comparative figures with the best type of Frise balanced aileron, and yawing-moment tests. These proved conclusively the remarkable efficiency of the floating aileron, considering the ratio of yawing moment to rolling moment as a measure of efficiency. The floating aileron was found to have a beneficial yawing-moment, that is, one which turns the airplane due to drag forces in the same direction as that desired due to rolling moment. This condition obtains for all except a very small portion of the range of wing and aileron angles tested.

This characteristic is of very great importance from the standpoint of safety, as it eliminates the necessity for using the rudder when turning a laterally stable airplane and thereby removes a very prevalent source of danger encountered by many pilots. We not only found this a desirable feature but also obtained figures to show a very substantial increase in rolling moment of the floating aileron compared with the Frise aileron at all except low angles of attack of the wing. As we are so vitally concerned with control at high wing-angles, this characteristic obviously is also extremely desirable.

Because of the low drag of these symmetrical-section ailerons, accompanied by the fact that the slots and flaps can be used over the complete span of the wing, a net gain in speed range is brought about by their use. This fact is believed to be of fundamental importance in connection with the realization of a speed range sufficiently high to include the required high and low speeds of the Competition.

How the Final Model Was Selected

As no special problem existed in the design of the tail surfaces of the Tanager, and with the above described tests completed, we now could determine the final airplane arrangement. Four or five general-arrangement drawings were prepared and studied. This study was believed to be sufficient to reduce the number to two, which were constructed in model form and completely tested in the tunnel. These arrangements are shown in Fig. 4, the chief difference between them being in the location of the body in relation to the biplane wing-structure. The advantages claimed for the upper arrangement were possible weight-saving due to landing-gear arrangement, increased landing-angle and possible improvement in efficiency. The lower arrangement, however, proved considerably better, as shown by the test results presented in Fig. 5, in which the rather remarkable L/D of 10.06 is shown.

In addition to obtaining the data plotted, the model selected as the final one was tested for stability and controllability in accordance with the usual tunnel methods. Complete runs were made both with and without slots and flaps incorporated. With the completion of these tests, the program of research and tunnel testing was concluded, so that the problems of structure, design,

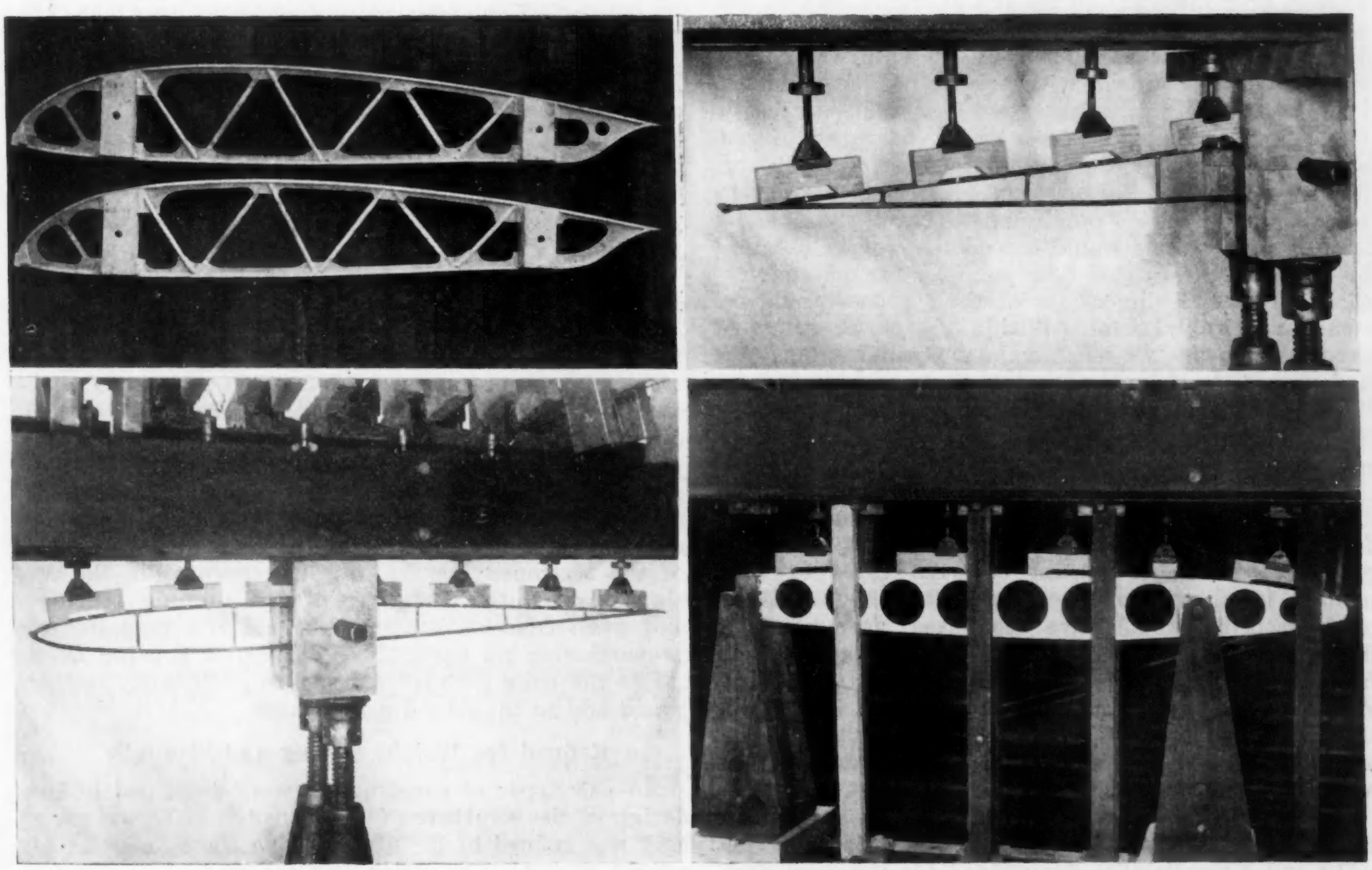


Fig. 6—Some of the Rib Sections Used in the Curtiss Tanager Airplane

Two Wing Ribs Are Shown at the Upper Left. The Upper Right View Is of an Elevator Rib Being Load-Tested. The Load Test of a Rudder Rib Is Illustrated at the Lower Left, and a Stabilizer Rib That Failed in the Test Is Shown at the Lower Left

weight saving and mechanism development could be started.

Design Problems

I shall now describe some of the considerations that prompted the particular arrangement of the Tanager. Some of the decisions affecting arrangement naturally had to be made at a stage of development prior to the construction and testing of the wind-tunnel model described.

Considerations of necessarily large wing-area accompanied by small unit-weight prompted the selection of the biplane wing-arrangement with overhung upper panel. This greater upper span is not so evident as would otherwise be the case, because of placing the ailerons at the tip of the lower wing, giving effectively equal upper and lower spans. The large gap and aspect ratio make for aerodynamic efficiency, whereas the pronounced stagger gives the pilot desirable visibility. The large dihedral-angle is, of course, used for lateral stability. As mentioned before, the wind-tunnel tests proved the better efficiency of the arrangement that located the upper wing above the fuselage on cabane struts, rather than hinged from the upper longitudinals with the lower wing below the fuselage on struts. A cabin fuselage was selected in preference to an open-cockpit type from considerations of resistance and practicability. One feature worthy of note in the fuselage is the bulged sides, which are rounded so as to fair in well with the radial air-cooled engine.

The powerplant selected was the Curtiss Challenger engine, then rated at 170 hp. at 1800 r.p.m. The actual engine used in the Competition had slightly more power than this, and the useful load in the ship was accordingly made to conform with this actual power on the basis of the rules. Because the rules required a useful load of 5 lb. per hp. and from the consideration of general design economy, an engine of from 150 to 200 hp. proved desirable. For an engine of smaller size, the weight of fuel and oil required for 3 hr. of flying and a load of two persons would exceed the weight obtained by applying the rule of 5 lb. per hp.; for a larger engine the over-all dimensions of the airplane would become undesirably great. Within the power range of greatest economy, we selected the particular engine that had proved itself by service test to be rugged and reliable; and during the 200 odd hours of testing by our own and the Fund pilots, no trouble of any kind connected with the powerplant was encountered.

Considerations of economy of weight and increased climbing efficiency, combined with the absence of need for higher speed, prompted the selection of a wooden propeller. Had the contest occurred three or four months later, without question a metal controllable-pitch propeller would have been used, as subsequent flight-tests have shown that substantial improvement in certain performance characteristics, notably climb and take-off, are obtainable by this means. Practically the same considerations determined the selection of the ordinary type of engine cowling in preference to the venturi type that was first tried out.

The proportioning of the fuselage length and of the tail-surface areas was based on considerations of stability and controllability determined for the most part from wind-tunnel tests.

The design of the landing-gear and tail-skid received very careful consideration. Aerodynamic analysis indicated that the airplane would descend at a vertical velocity substantially greater than do airplanes having conventional airfoil arrangements. This made necessary the designing of a landing-gear of unusual ruggedness and possessing shock-cushioning properties of large energy absorption and dissipation. A large-stroke oleo shock-absorber was chosen for both the landing-gear and the tail-skid. The later flight-tests proved the wisdom of these criteria in the landing-gear design, as the confidence gained by the pilots in landing the airplane in fully stalled condition from great heights, which was obtained by repeatedly and successfully negotiating such landings, contributed considerable to the excellent landing figures of merit achieved. This was further emphasized by the necessity for landing certain competing airplanes with far less abandon, because of failures occurring during the Competition. Another feature of the landing-gear which was of importance in increasing the high speed was the incorporation of a control that made possible the retraction of the landing-gear to the extent of pulling up the wheels through the length of the oleo stroke.

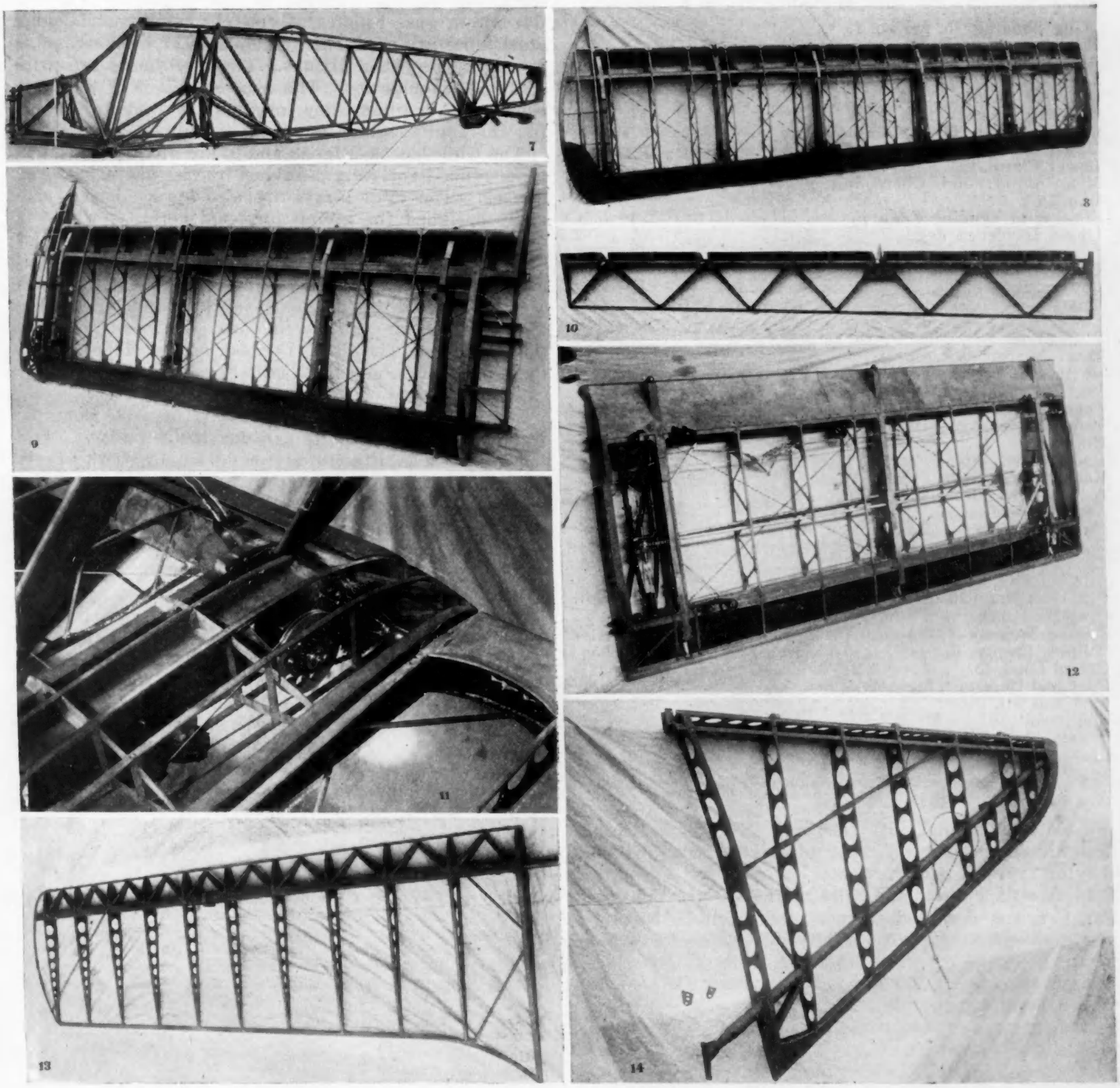
Interesting Points in Mechanism Design

From the standpoint of mechanism design, the features of greatest interest were the slot mounting, the flap control and the floating-aileron control. I previously mentioned the necessity for mounting the auxiliary airfoil on a special rod-on-roller mechanism, the strength and shape of the rods being determined from the special tunnel tests on a 20 x 20-in. model airfoil. A further mechanism that ensured the formation of a slot of equal chord along the span was necessary and was designed and developed. The noteworthy point and the feature requiring most ingenuity in designing the flap control was the mechanism that made the control irreversible. In addition, the control had to be geared so as to permit lowering or raising the flaps in a reasonable time. The necessity for rigging the control so as to ensure coincident and parallel movement of the five distinct flaps used also required careful design.

The floating-aileron control had to be arranged to permit the following action: The right and left ailerons must be free to align themselves with the direction of the relative wind, no matter what the attitude of the airplane, and must also be susceptible of relative positive and negative displacement with respect to each other by virtue of lateral stick-movement. Several systems that would perform these functions were laid out and the one selected as having the most promise was developed thoroughly by tryout on a small model. The device worked perfectly in the full-scale airplane. Some of the accompanying features incorporated in the design involved the designing of self-aligning bearings and gear-reduction mechanisms and the necessity of proportioning all parts so as to permit housing them inside the wing without recourse to protuberances that would add to the parasite resistance.

Refined for Weight Saving and Strength

No new types of construction were developed in the design of the structure of the Tanager, although every part was refined to the utmost from the standpoint of weight saving. The policy was followed of utilizing a construction material for each component part which would be best adapted for that part as regards weight saving, strength, ruggedness and susceptibility to rea-



GROUP OF SOME STRUCTURAL MEMBERS

Fig. 7—The Fuselage Skeleton Which Was Constructed Almost Entirely of Duralumin Tubing Secured at the Joints by Riveted Gusset-Plates of the Same Material

Fig. 9—Looking Down on the Left Lower Wing

Fig. 11—Left Lower Wing-Tip Showing the Floating-Aileron Control. This, Like All Other Controls, Is of Cable Running over Ball-Bearing Bakelite and Duralumin Pulleys

Fig. 13—Framework of the Floating Aileron

Fig. 8—Top View of the Left Upper Outer Wing. The Beams Are of the Spruce-Box Type with Tapered Flanges To Reduce Weight

Fig. 10—Bottom View of the Right Lower Flap. This Framework Was Afterward Covered with Sheet Duralumin and Cloth

Fig. 12—Center Panel Showing Control Screw for Upper-Panel Flaps

Fig. 14—Stabilizer Framework

TABLE 1—PRINCIPAL CHARACTERISTICS OF THE CURTISS TANAGER AIRPLANE

Wing Loading, lb. per sq. ft.	8.5
Power Loading, lb. per hp.	16.1
Airfoil Section	Curtiss C-72 with Wing-Slot and Flap
Load Factor	7
Over-All Length, ft.-in.	26—8
Over-All Height, ft.-in.	11—4
Over-All Span, ft.-in.	43—10
Upper Chord, in.	60
Lower Chord, in.	60
Mean Aerodynamic Chord, in.	60
Gap, in.	69
Stagger at Leading Edge, in.	29½
Upper Incidence, deg.	—2
Lower Incidence, deg.	—2
Upper Dihedral, deg.	4
Lower Dihedral, deg.	4
Upper Sweepback, deg.	0
Lower Sweepback, deg.	0
Wing Area, Including Flaps, sq. ft.	333
Total Aileron Area, sq. ft.	45
Horizontal Tail-Area, sq. ft.	47.6
Vertical Tail-Area, sq. ft.	20.4
Total Elevator Area, sq. ft.	23.4
Total Rudder Area, sq. .ft.	14.1
Engine	Curtiss Challenger
Rated Power, hp.	170
Rated Speed, r.p.m.	1,800
Actual Power Developed, hp.	176
Actual Speed, r.p.m.	1,830
Full-Throttle Fuel-Consumption, lb. per hr.	89.3
Full-Throttle Oil-Consumption, lb. per hr.	3.4
Fuel Capacity, gal.	57.5
Oil Capacity, gal.	3
Propeller Material	Wood
Propeller Diameter, ft.-in.	8—4½
Cooling Medium	Air
Weight, Empty, lb.	1,959
Useful Load, lb.	882[a]
Pilot and Observer, lb.	370[a]
Fuel and Oil, lb.	359[a]
Equipment, lb.	68[a]
Ballast, lb.	85[a]
Gross Weight, lb.	2,841

[a] For the Guggenheim Safe-Aircraft Competition.

sonable construction. By following this policy a light design resulted, using a great number of materials and varying types of construction.

In accordance with the rules of the Competition, the Tanager was designed to meet the strength requirements and the loading conditions of the Department of Commerce. We departed from the Department's rules only in the case of certain parts that we designed to meet conditions of a larger load-factor than was required, because of conditions of special severity which we believed would exist, as in the case of the landing-gear, or of conditions which were not adequately covered because of paucity of aerodynamics data then existent and which we were able to supplement, such as the loading of the auxiliary airfoil.

Such static tests as were necessary were conducted. These included the testing of miscellaneous fittings and wing and tail-surface ribs. Some of these parts being tested are shown in Fig. 6.

Construction and Materials of Structural Units

I shall now give a brief description of the type of construction and materials used in the various units of the airplane, illustrating by photographs as representing the best means of conveying such description. These photographs are reproduced as Figs. 7 to 19 and are, I believe, sufficiently clear to show the part described.

The fuselage, Fig. 7, is constructed almost entirely of duralumin tubing secured at the joints by riveted-duralumin gusset-plates. A few chromium-molybdenum steel tubes are used, chiefly at points of high stress, as are also a few steel fittings. The rivets used are principally of tubular steel. The truss system is of the Warren type. Aluminum-alloy forgings are used for mounting the engine, which is swung in rubber supports.

The wing beams, Figs. 8 and 9, are of the spruce-box type, refined for weight saving by the use of tapered flanges. The drag struts are also spruce boxes, specially designed for giving torsional rigidity, which is necessitated by the high concentrated flap and slot loads. The wing fittings are of both steel and duralumin, and the drag wires are steel tie-rods. The ribs are of wood and the wings are fabric-covered except for duralumin sheets at the front and veneer at the rear slot-openings. The flaps, Fig. 10, are of cloth-covered sheet duralumin, and the auxiliary airfoils are of laminated spruce and sheet duralumin.

The controls, Figs. 11 and 12, are of cable running over ball-bearing Bakelite and duralumin pulleys. The floating ailerons, Fig. 13, are of duralumin, both beams and ribs, with steel fittings and cloth covering. The horizontal stabilizer, Fig. 14, embodies the same general type of construction as that used in the ailerons and flaps, whereas the rudder, elevators (See Fig. 15) and fin are made of welded steel-tubing. The cabin fairing is of light wooden strips.

TABLE 2—CURTISS TANAGER FLIGHT-TEST DATA OBTAINED BY THE GUGGENHEIM FUND TEST-SECTION

	Actual	Required
Minimum Flying-Speed		
Slot Open, Flap Down, m.p.h.	30.6	35
Slot Open, Flap Neutral, m.p.h.	34.8	
Slot Closed, Flap Neutral, m.p.h.	41.5	
Slot Closed, Flap Down, m.p.h.	35.4	
Minimum Gliding-Speed		
Slot Open, Flap Down, m.p.h.	37.1	38
Slot Open, Flap Neutral, m.p.h.	42.1	
Slot Closed, Flap Neutral, m.p.h.	48.8	
Slot Closed, Flap Down, m.p.h.	41.5	
High Speed, m.p.h.	111.6	110
Take-Off Distance in Still Air, ft.	295	300
Distance To Clear 35-Ft. Obstacle from Start of Take-Off Run in Still Air, ft.	500	500
Run after Landing in Still Air, ft.	90	100
Distance Covered in Landing in Still Air over 35-Ft. Obstacle and Stopping, Measured from Base of Obstacle, ft.	293	300
Climb, ft. per min.	700	400
Flattest Glide, deg.	6	8
Steepest Glide, deg.	13.2	12
Longitudinal Stability	OK	—

General Stability.—Will fly at any air speed from 45 to 100 m.p.h. at any throttle opening for 5 min. in gusty air with hands off controls.

Control in Case of Engine Failure.—Takes up a steady gliding attitude with all power switched off and controls free. If elevator is pulled back, airplane will glide at a speed of 37 m.p.h.

Ability To Recover from Violent Disturbances.—Dived to speed 20 per cent above level-flying speed, will take up a steady glide if all controls are released. Will do this trimmed for any speed between 80 and 110 m.p.h. Trimmed at full throttle at any speed from 45 to 75 m.p.h. with power cut-off and abnormal attitude obtained by moving controls, will recover by itself in less than 500 ft. with controls free or 250 ft. if controlled.

Maneuverability in Restricted Territory.—Will take off from a 500-ft. square surrounded by a 25-ft. obstacle and land in same square with engine cut off soon after take-off. Can be taxied in a 20-m.p.h. wind without assistance.

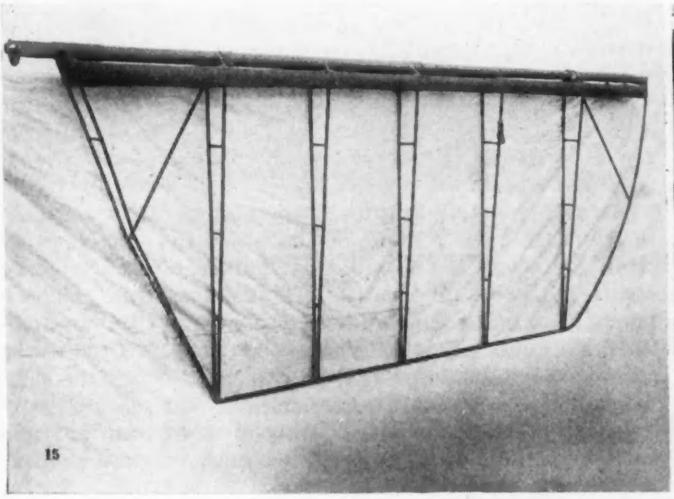
Figs. 16 and 18 indicate the extremely large movement furnished the stabilizer by a screw located on the center line of the fuselage. The rubber discs in the tail-skid for taxiing and its long oleo-stroke are also shown. Riveted duralumin fuel and welded aluminum oil tanks, shown in Fig. 17, are used, these being mounted in the side fairing of the fuselage.

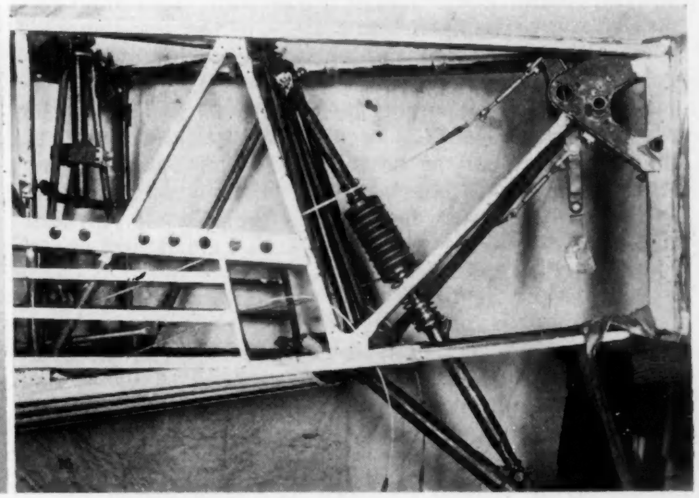
Dimensional and Flight Characteristics

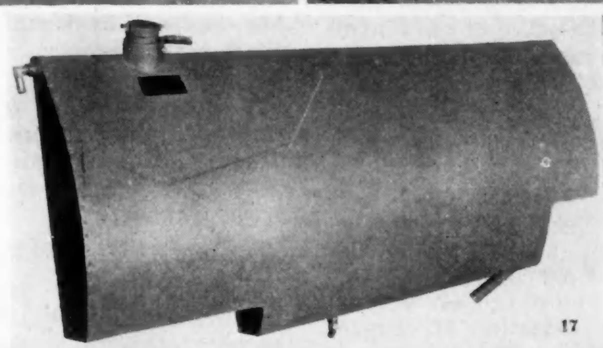
Table 1 gives the main dimensional characteristics of the Tanager, including areas, loadings, weights and capacities.

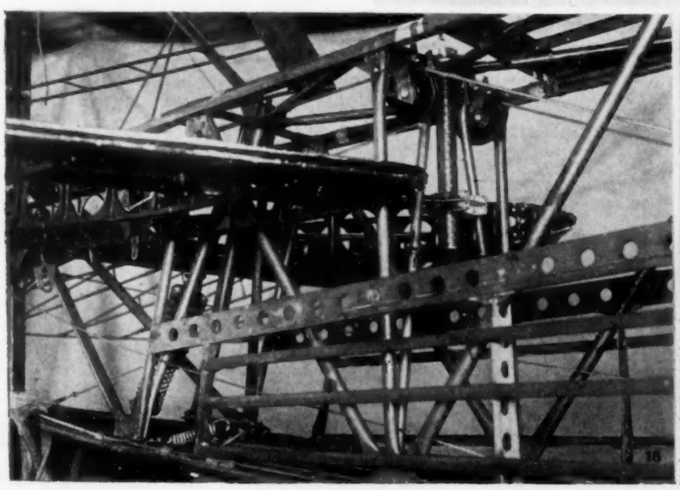
In Table 2 I have listed the actual flight-characteristics of the airplane as obtained by the Competition pilots. I desire here to summarize and comment briefly on these figures. The minimum flying-speed is 30.6 m.p.h.; the minimum gliding-speed, 37.1 m.p.h.; and the high speed, 112 m.p.h. This gives a flying-speed range of 3.7 and a value of just over 3 for the ratio of minimum gliding-speed to maximum speed. In considering these figures, the fact must be borne in mind that they are actual accurately determined values, which are not susceptible of doubt or suspicion and therefore are not readily comparable with corresponding figures for commercial airplanes as currently advertised. However, I have available reliable flight-test information on several widely used commercial airplanes that are at least the equal in performance of the best on the market. This is presented in Table 3.

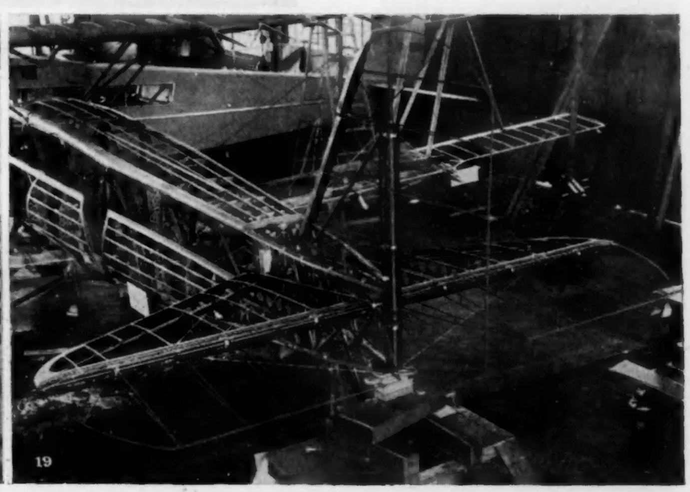
From Table 3, we see that few, if any, commercial planes are in existence that actually attain a speed range of 2.5, the average being between 2.1 and 2.4. This fact is seldom realized, principally because of the incorrect claims advertised by many construc-











ANOTHER GROUP OF STRUCTURAL MEMBERS

Fig. 15—Framework of the Elevator

Fig. 16—Tail-Skid, Elevator Horn and Rear End of Fuselage

Fig. 17—Riveted Duralumin Fuel Tank That Is Mounted in the Side Fairing of the Fuselage

Fig. 18—Tail Unit

Fig. 19—Tail Surfaces Assembled in Airplane

TABLE 3—FLIGHT-TEST DATA ON COMMERCIAL AIRPLANES

Type of Plane	Power, Hp.	Speed, M.P.H., Minimum	Maximum	Speed Range
Small Cabin	170	56.5	120	2.12
Large Mail	600	62.5	150	2.4
Medium-Size Cabin	225	57.8	122	2.12
Medium-Size Cabin	450	63	135	2.14
Training	170	45.2	104	2.3
Large Transport	1,200	57	138.9	2.4

tors. The actual attainment, therefore, of a speed range of over 3 is the more remarkable and explains the rapid elimination from the competition of all stock commercial airplanes, even though possessing some improvements, and probably in some cases to the astonishment of the contestant, who no doubt believed his own exaggerated performance figures.

The remaining performance figures, including the climb, maneuverability, controllability and stability characteristics can be best judged from Table 2. One other landmark to bear in mind when comparing this with other airplanes, however, is the take-off run and landing distance, for which a figure of merit just under 300 ft. applies in each case.

Safety Features

Let us now consider some of the safety features of the Tanager. First, undoubtedly, should be listed the slow speed of flight that is possible. This is brought about, not only by the ability of the *airplane* to fly slowly, but also by the ability of the *pilot* to fly it slowly with accompanying control and safety. The safety is therefore more than doubled, as, first, because of the control, the likelihood of striking the ground in any but a normal attitude is very slight, and, second, that the impact on striking in an abnormal attitude, should it occur, will be only one-fourth as great as with an airplane flying twice as fast, as do many now in use, which are generally considered to land satisfactorily. The control here mentioned, and which is distinctive of the Tanager, is centered around the floating aileron, the aerodynamic qualities of which were previously described. They furnish their control when most needed, at stalling speeds, and without the introduction of adverse yawing-moments. These qualities greatly reduce, and almost eliminate, in fact, the necessity for accurate depth perception in the pilot. To land the Tanager, it is necessary merely to hold the stick all the way back and wait for the earth to come up, which it will appear to do rapidly but with no more shock on landing than with the conventional airplane.

FIG. 20—SIDE VIEW SHOWING THE FRONT SLOT OPEN

The freedom from any tendency to fall off to one side or the other when in stalled flight is a remarkable experience for one when first flying the plane. The *feeling* of safety, as well as its *reality*, is present.

Accident statistics bear out the danger lurking behind the incipient spin. That the Tanager cannot accidentally be made to spin can be definitely stated, as so far no one has succeeded in purposely spinning it, even though repeated attempts have been made by experienced pilots. The airplane will neither spin nor violently dive if the power is cut-off during a stalled power-on flight, which action places the machine momentarily at an angle greater than that required for its minimum power-off flight, or beyond its stalling angle. This test was made close to the ground during the Competition tests and satisfactory two-point landings resulted.

A further safety feature is the ability of the airplane to maintain a steep angle of climb and thus successfully clear obstacles that would, under similar conditions, be struck by the usual airplane. This steep angle of climb is emphasized as distinguished from steep rate of climb, in which quality no advantage exists for the Tanager as compared with many other airplanes.

Another safety feature, associated with the non-yawing characteristics of the floating ailerons, is the elimination of the necessity for that most abused control, the rudder, for normal flying and turning maneuvers. Any degree of bank can be imposed on the airplane with result that a properly executed turn is made without the use of the rudder. By properly executed, I mean that no resultant slip or skid ensues. This feature, I believe will more and more prove valuable and will emphasize the importance of the floating aileron of the general arrangement developed and successfully proved on the Tanager.

Flight Tests

When, on Oct. 12, 1929, after two years' of development research and design work, the Tanager first took the air, considerable excitement and no little concern was felt by those responsible for the design, who were witnesses of the event. Yet I cannot refrain from stating that nothing functioned improperly and that, aside from lengthening the stabilizer-adjustment screw and modifying the cowling and propeller, because of a desire to secure slightly more favorable performance, nothing was altered or hardly even adjusted on the airplane during the ensuing three months of the preliminary and Competition tests. The designers' tests ran from Oct. 12 to 29, after which the airplane was delivered to the Fund for Competition tests. During this period the Competition requirements were checked and the performance obtained was found to coincide almost precisely with predicted figures.

The tests conducted by the Fund pilots were divided into three classes: qualifying, safety and Competition rating tests. In the first group, maximum speed and rate of climb were checked, as were also various airplane characteristics such as strength, powerplant, loading, instruments, visibility and fire risk, all of which were susceptible of check by inspection. Several airplanes were disqualified by these tests. Next the safety tests and demonstrations were conducted. A

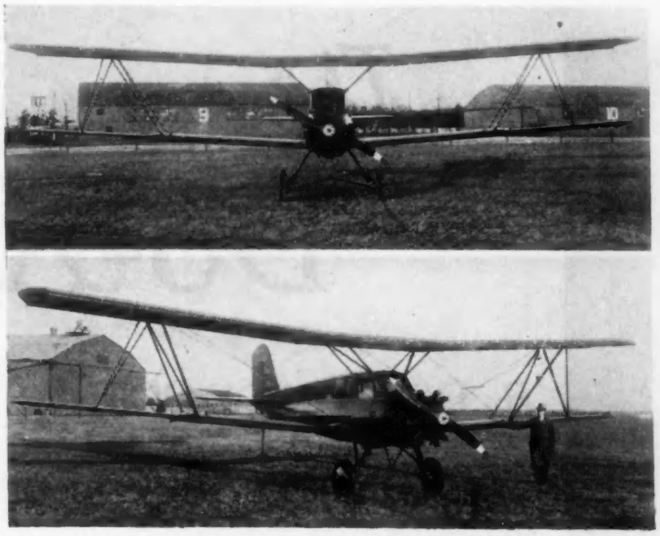


FIG. 21—FRONT AND THREE-QUARTER VIEWS
The Cleanness of the Design Is Apparent in the Former

rigorous test-program was undertaken for each contestant, as all of these requirements had to be met to make an entry eligible for the final testing for points to determine the winner. The Tanager was the only entry to meet all safety-test requirements. The official flight-test data applying to this airplane and as obtained by the Fund's flight-test section have been given in Table 2. Because of these results, the Tanager was pronounced the winner of the Competition.

Fig. 20 is a side view of the airplane and gives a good view of the slots, flaps and floating aileron. Fig. 21 presents front and three-quarter views, and attention is particularly drawn to the cleanness of the design as shown in the front view. Fig. 22 shows the remarkable angle of climb which the plane negotiated when clearing the obstacle during the Competition tests.

Conclusion

In describing the design and development of the Tanager, I have attempted to bring home the fact that a task really vital to aviation has been accomplished; it has been carried through to successful completion only by virtue of painstaking research and development work, and the safety features incorporated in the airplane are readily susceptible of adaptation to otherwise conventional designs in general.

In commercial aviation the fundamental requirements of the airplane are safety, reliability and economy. By economy is meant the ability to transport a reasonable pay-load safely and reliably at a low cost and at a speed greater than that obtainable by other means of transportation. The safety features, accompanied by improved performance-characteristics, developed in the Tanager, enhancing as they do the fundamental requirements necessary to bring aviation to its proper place, represent a very real advance in the art. If such is the case, the designers of the Tanager will have received their greatest reward.

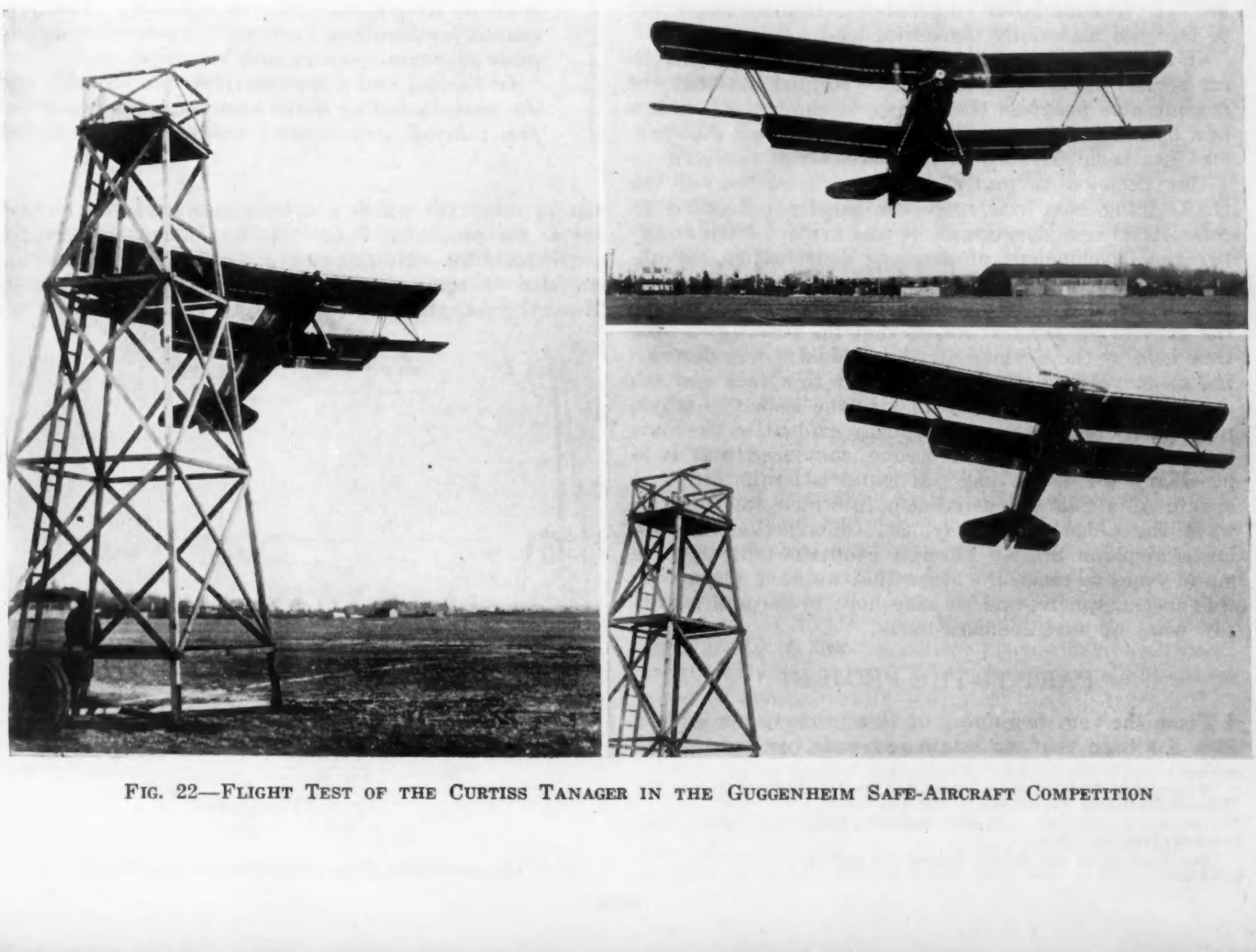
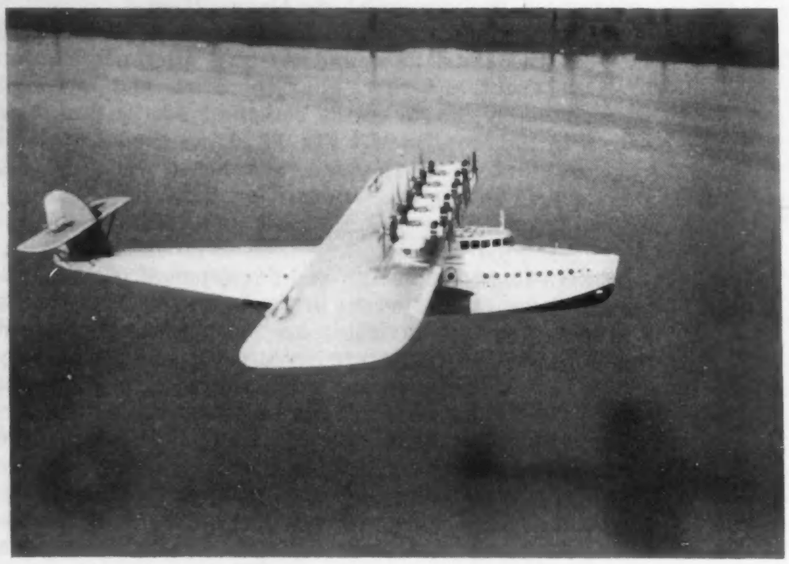


FIG. 22—FLIGHT TEST OF THE CURTISS TANAGER IN THE GUGGENHEIM SAFE-AIRCRAFT COMPETITION



The Do-X

By DR. CLAUDE DORNIER[2]

METROPOLITAN AERONAUTIC MEETING PAPER

ECONOMIC considerations caused us to decide to build the first flying boat. We considered that the profitable carrying of passengers would not become possible until a large number can be conveyed simultaneously, as in other forms of transport. To assure the necessary popularity, which at present is lacking, the traveling public must be offered more safety, space and comfort than has been offered up to the present. It was moreover considered extremely important to increase materially the useful load.

In a paper[3] which I gave before the Royal Aeronautical Society in London, in 1928, I pointed out that the considerable progress then being attempted, which has now been achieved, was mainly due to the fact that payload has been extraordinarily increased at one step.

Our decision to undertake the construction of the Do-X flying boat was moreover greatly influenced by commercial considerations. It was evident from studying the development of airplane construction, of all-metal planes in particular, that practical experience in the direction of building smaller airplanes had become the general property of all, so that the start for a long time held by the German airplane industry was decreasing from year to year. In view of this fact and the development of the American airplane industry, which will shortly become very practically evident in the markets of the world, I have become convinced that it is necessary for us to pay particular attention to that sphere of airplane construction in which we were always the pioneers; namely, the construction of very large airplane units. Foreign countries will require many years to reach the stage that we have reached in this special sphere, and we may hope to surpass tomorrow what we have achieved today.

The first of the seven parts of this paper covers the considerations and conditions that determine the scope of the project and the method of procedure in developing the design. The structural features are described in Part 2, in which particular attention is given to the distinctive engine arrangement and mounting, the hull construction and the effect that increasing the size has on the ratio of weight and cost to capacity. The provisions for handling fuel and oil for relieving the pilot of engine supervision are explained.

In Parts 3 and 4 are described the reaction and the tests, including the dramatic experience of the first take-off, which came unintentionally during

PART 1—THE PROJECT

From the very beginning of this project, our leading idea has been that, to attain our ends, we must make use of only that which had been subjected to practical tests; we precluded from consideration every kind of experimenting. No doubt, we were hampered by this decision to some degree in our creative development. Nevertheless, the fact that barely 100 working hours

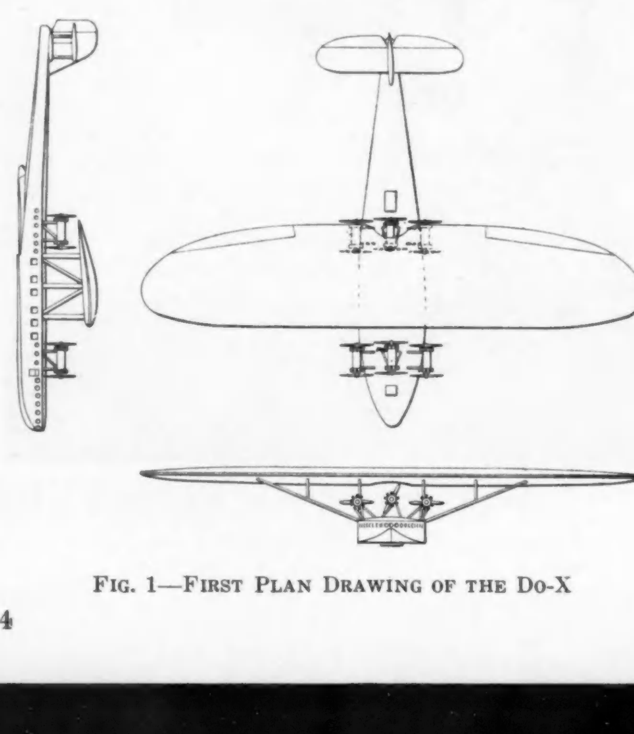


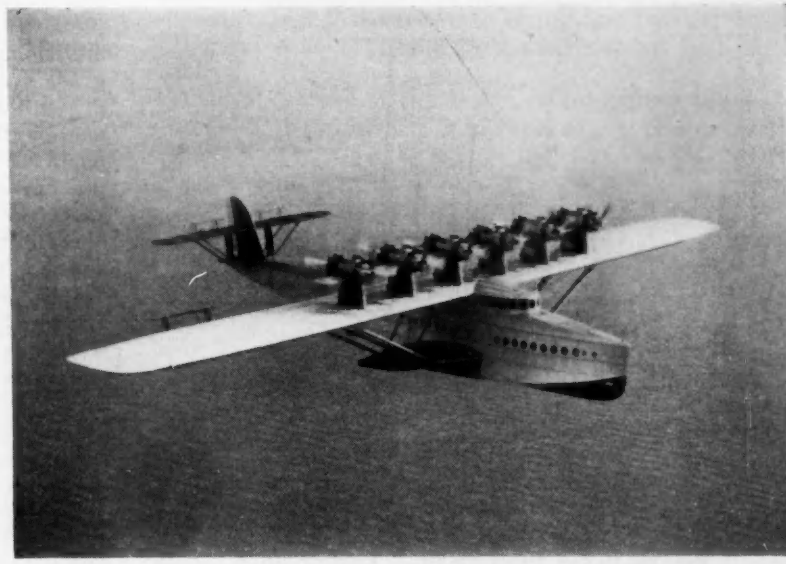
FIG. 1—FIRST PLAN DRAWING OF THE DO-X

[1] Translated from a paper presented by Dr. Dornier before the Wissenschaftliche Gesellschaft für Luftfahrt.

[2] General manager, Dornier Metallbauten Gesellschaft mit beschränkter Haftung.

[3] See *Journal of the Royal Aeronautic Society*, December, 1928, p. 980.

Flying Ship[1]



Illustrated with PHOTOGRAPHS, DRAWINGS AND CHARTS

a taxying test. Adjustments are reported that had to be made in the control surfaces and mechanism and in the cooling of the rear engines.

Part 5 is featured by a comparison between weights and performance projected and those secured in the actual trials and includes a graph showing the relation between loads and cruising radius. The economic possibilities are outlined in Part 6, which draws a clear distinction between possible record achievements and practical commercial operation. Part 7 features a graph showing the trend in flying-boat size and predicts economic success for the larger craft without the artificial aid of subsidies.

was required for changes between the beginning of our trials with the flying ship and the performance of the final definite test flights, in conjunction with the flying performance attained, proves that the procedure adopted by us was right.

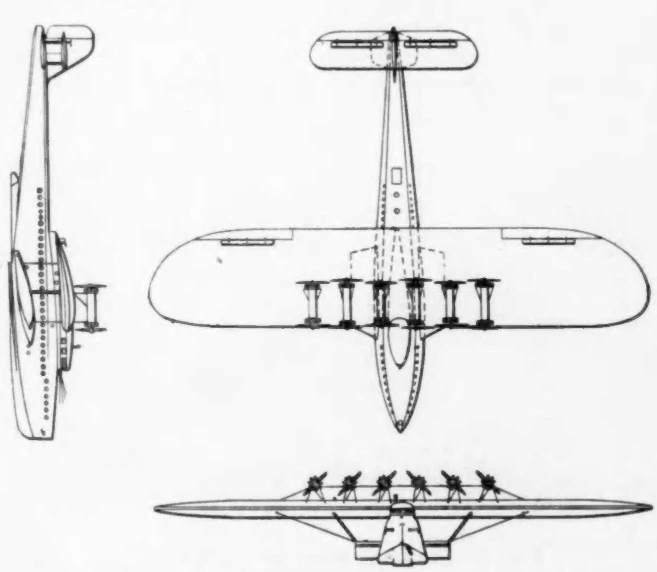


FIG. 2—PLAN OF DO-X APPROACHING ITS FINAL FORM

The preliminary work of building our first flying ship dates back to 1924. The first consideration was the hull, as it was evident from the first that the flying ship must be in the form of a boat. The question of whether it should be a monoplane or a multiplane was not so simple, but the decision in favor of the monoplane type came comparatively soon.

The first project drawing bears the date of September 27, 1924. As may be seen from Fig. 1, the first intention was to have a so-called self-stabilizing boat requiring no further support because of its great breadth. Discussion of the many variants which we worked out before arriving at the form reproduced in Fig 2, dated June 26, 1926, will be omitted.

We made much use of models in working out the project. Both the 6-meter-wide (20 ft.) boat, which was first planned, and the boat which was actually built were erected to full scale in wood, with complete tail control elements. Fig. 3 shows the final form of the plans. We began the work in our designing offices on Dec. 22, 1926; and, aside from a change in the stumps, to which I shall refer later, only trifling deviations were made in the course of this work from the design shown in Fig. 3. Both the design and work were kept secret for a long time.

Flying with Twelve Engines

The first 1924 plan provided for seven engines with a total output of 4200 hp.; but the 12 engines with a total output of 5800 hp. were later decided upon, and the powerplant that was installed actually provided 6300 hp., because the performance of the engines employed has been increased. The main consideration which caused us to decide upon 12 engines is the fact that units of 800 to 1000 hp., such as would have been necessary if only seven were used, are not so reliable as engines of approximately 500 hp.

One of the most difficult matters for us to decide was the choice and arrangement of the engines. We took two years to decide the question as to whether the engines should be water or air-cooled and as to how they should be installed; independently, in the wing or in the boat. The fact that we ultimately decided upon the present arrangement signifies only that I regarded this

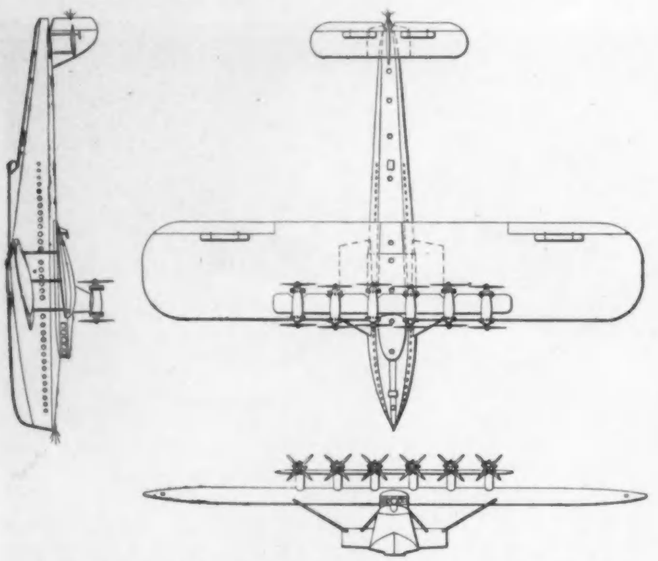


FIG. 3—FINAL PLAN OF DO-X FLYING BOAT

Very Slight Departures Were Made from This Plan in the Boat As Erected

solution, both then and now, as the best compromise.

The decisive factor in the selection of the air-cooled engine for the first flying ship was the fact that, in comparison with water-cooled engines, it would be possible to save over 3000 kg. (6615 lb.) in weight. This saving of weight is so considerable that it would not be compensated for by the somewhat smaller consumption of fuel by water-cooled engines, in view of the length of time during which the engines would be actually running.

The tandem installation of the engines was the necessary result of their number. This, with its advantages and disadvantages, has been for more than 10 years our usual form of installation. It is at present the easiest and safest way of installing the engines whenever a comparatively large number is required, and for that reason it is the arrangement that is being adopted more and more everywhere. One might almost say that tandem installation, by creating double engines, reduces the number of units by one-half. A tandem pair of nine-cylinder engines is scarcely more complicated than a single 18-cylinder engine, but it is considerably more reliable. The smaller engine is safer than the larger, by itself; and only one-half of the power is lost in the event of trouble with engine, gear or propeller. The resistance of a nacelle fitted with double engines, including the supports, is not greater than that of a nacelle for one large engine, and the propeller diameter and tip speed are considerably smaller.

The data for the aerodynamic calculations were obtained from experiments in Göttingen and in the wind tunnel of the Zeppelin airship company. Because of the magnitude of the undertaking, we proceeded most methodically in making our investigations and spared neither time nor money.

Auxiliary Wing Aids Lift Materially

As the small plane above the main wing has attracted very great general attention, I will show in Fig. 4 the polar curves of the flying ship. The slightly outlying curve A represents the upper wing without the engine nacelles and their supports. This would correspond to the ideal case in which the engines are installed completely in the interior of the boat or the wing and no additional resistance is caused by the cooling of the engines and the bearings of the propellers. The heavily drawn line B is the polar curve of the flying ship in its present form, when gliding, and the dotted line C is the polar curve of the same ship when traveling with rotating propellers. The broken dotted curve, line D, represents the ship with the engine nacelles and their supports but without the auxiliary plane. The calculation is based upon the surface of the main wing.

It is clear that the auxiliary plane causes a slight reduction in resistance at small angles of incidence. At larger angles of incidence, this insignificant diminution in resistance is supplemented by an appreciable increase in lift. The polar curve A is ideal and practically impossible to attain, as provision must be made for cooling the engines, even if they are enclosed in the wing or in the boat, and this involves consumption of power and consequent loss of speed, as superficial cooling is only possible for racing planes. Installing the propellers independently necessitates heavy gears, which easily get out of order, and additional friction from their bearings. Previous experience did not justify such complications.

The same applies to driving one propeller by two or more engines. Moreover, the large propellers required with this arrangement cannot be adequately protected against water spray. In developing the design, it became evident that considerable difficulties occur in satisfactorily obtaining the radial space necessary for the propellers required with an output of 6000 hp.

It is now commonly known that the lift is consider-

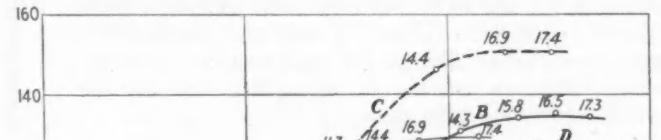


FIG. 4—POLAR CURVES OF THE DO-X

ably increased by having propellers rotating above the wing. We have also very thoroughly tested the possibility of having pusher propellers fitted to the trailing edge of the wing with the engines inside the wing. We have come to the conclusion that the long shafts and the heavy bearings involved would place excessive weight on the trailing edge, which would largely counteract the aerodynamic advantage that might be gained.

After deciding, in the first stages of our work, that our craft must be a boat with central boat-body, our next object was to obtain the necessary stability without the use of supplementary displacement bodies. It became evident, however, that this was not possible in view of the dimensions involved, without at the same time risking considerable disadvantages. We therefore had to resort to the stump design which has proved its value hundreds of times for more than 10 years.

Under-Water Design of the Hull

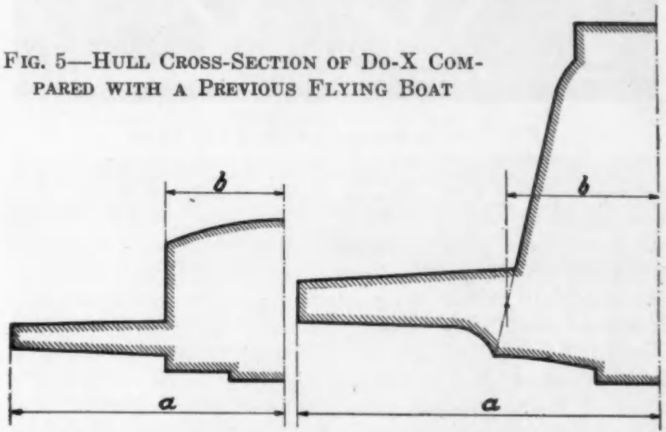
The form under the water-line, so far as this affects the action in starting, was very little changed in comparison with boats previously built. The central longitudinal step has been retained. At its rear end it is transversely horizontal to the direction of flight and becomes slightly dihedral toward the fore. The parts of the boat bottom situated beside the longitudinal step are slightly concave. The forepart of the ship is sharply keeled, particularly in those parts which lie above the water-line when starting in calm water.

The stumps are sharply rounded transversely to the direction of flight where they pass through the side of the boat. This new stump form, which was not provided for in the original project, has static and hydrodynamic advantages. The structural depth of the stumps at the base is considerably greater, which makes possible more rigid construction of the supporting members. When starting, the water is quickly displaced by this rounded form, whereas it collected in the corner between the bottom of the stump and the boat side of the old design.

A schematic cross-section at the main step of the Do-X is shown at the right in Fig. 5, and on the left is shown for comparison a similar section through the Dornier Wal flying boat. It is worthy of note that the ratio of the breadth of the boat *a*, over the stump, to the breadth *b*, of the actual boat body, decreases with the increase in size. This ratio amounts to about 2.92:1 in the Libelle, the smallest boat built by us, having a flying weight of approximately 670 kg. (1477 lb.); it falls to 2.46:1 in the Wal type and to 2.12:1 in the Do-X flying ship. I anticipate that the stumps will be only rudimentary for boats of 100 metric tons (110¼ net tons), and that the larger flying craft of the future will require no supplementary displacement bodies for stability.

A novel feature of the design of the hull of the flying ship Do-X is its division into three decks, this being the first time that this form of construction has actually been put into practice for an airplane. The arrangement is shown in Fig 6. On the upper deck are the so-called captain's bridge, the pilot's compartment, the officers' room, the switch room and the rooms for wireless and auxiliary machinery.

FIG. 5—HULL CROSS-SECTION OF DO-X COMPARED WITH A PREVIOUS FLYING BOAT



The middle deck is intended exclusively for passengers. It is 23.5 m. (77 ft. 1¼ in.) long, about 2 m. (6 ft. 6¾ in.) high and 3.5 m. (11 ft. 5 11/16 in.) wide at the widest point. On the bottom deck are the fuel and oil, stores, freight and luggage.

Much designing time and labor was spent in settling questions concerning statics. The full-cantilever design of wing was rejected, to make the plane as light as possible. The semi-cantilever form of wing was chosen also for manufacturing reasons.

The wing has three spars and is designed with a triple abutment support. This construction is original with the Do-X, and it affords exceptional rigidity and torsional strength. Moreover it gives us the assurance that damage to a single strut or spar cannot affect dangerously the supporting capacity of the whole structure.

PART 2—STRUCTURAL FEATURES

I will now proceed to explain as briefly as possible the most important structural features of the flying ship.

The plan of the wing is rectangular, with slightly

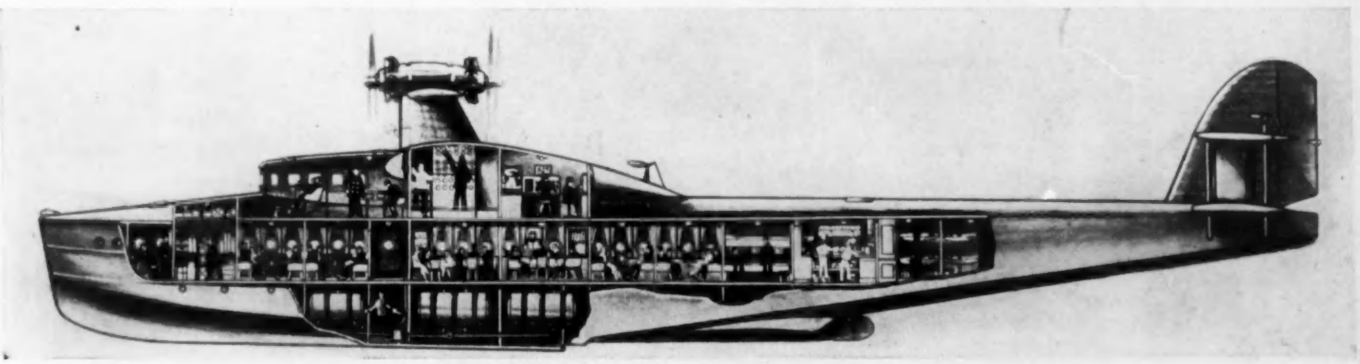


FIG. 6—SCHEMATIC LONGITUDINAL SECTION OF HULL

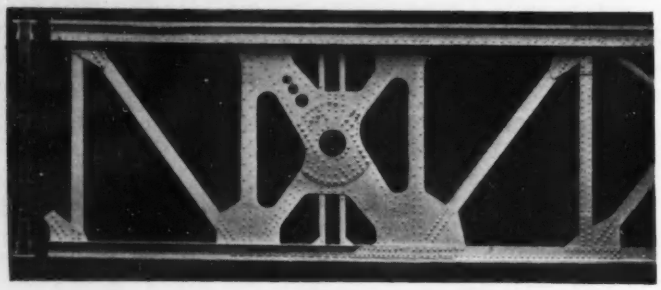


Fig. 7—Construction of Main Spar

rounded tips. The span is 48 m. (157 ft. 5¾ in.) and the chord 9.5 m. (31 ft. 2 in.). The total projected wing surface, including the ailerons and the upper wing, is 486.2 sq. m. (3233.4 sq. ft.). The weight of the complete wing—with ailerons, upper wing and the complete abutment support—is 7559 kg. (16,664¾ lb.). The unit weight of the wing therefore amounts to 15.5 kg. per sq. m. (3.17 lb. per sq. ft.). The wing complies with the existing regulations of the Deutsche Versuchsanstalt für Luftfahrt when the total weight of the flying ship amounts to 52 metric tons (57½ net tons). The middle spar is located at about the point of maximum profile height. The front and rear spars are wide apart; each 2.8 m. (9 ft. 2¼ in.) from the middle spar. Cross members between the spars are spaced up to 3.6 m. (11 ft. 9¾ in.) apart. [These members are not designated as ribs because we understand that they do not follow the outline of the wing.—Editor.] None of the weight or stress of the main supporting system is carried by the upper wing; its only static function is to add to the rigidity of the engine supports.

The whole framework of the wing, with the exception of certain steel fittings, is made of duralumin. This might lead to the conclusion that I have changed my views concerning the advisability of utilizing steel in airplane construction; but I have not changed my views in this respect. It was merely impossible to obtain soon enough the steel angle and plates of the dimensions necessary. I regard the use of steel as having a great future—especially in very large machines, the structural parts of which have sections in which steel can be used to the best advantage.

A view and section of that part of the middle spar to which the strut is attached are shown in Fig. 7. The girders of the spars are of pressed duralumin angles and plates, similar to the shapes used in bridge building. Supplementary plates are utilized at various points, according to the stress. At points where the stress upon the girders is not so great, the vertical webs of the angles are machined out to save weight. The design of the front and rear spars is similar to that of the middle spar.

The spars afford a good example of the common experience that less work is required per unit of weight to fabricate structural members of greater dimensions, because the amount of work depends mainly upon the number of joints and rivets. The Do-X has an average of 2.5, the Dornier Superwal has 3.3 and the Dornier Wal 5.2 joints per meter (39.37 in.). Similarly, the number of rivets per kilogram (2.205 lb.) of finished spars is 9.8 for the Do-X, 33 for the Superwal and 44 for the Wal.

Trestles Built for Testing the Spars

We spent many months in developing the design of the spars, which today seems so obvious, because it was indispensable to make a trial spar and to test it by putting it under stress in all directions. Special foundation work was necessary to make rigid the special trestles that had to be constructed for the test, as the breaking strain for one-half of a spar amounts to almost 42.5 metric tons (47 net tons). The usual method

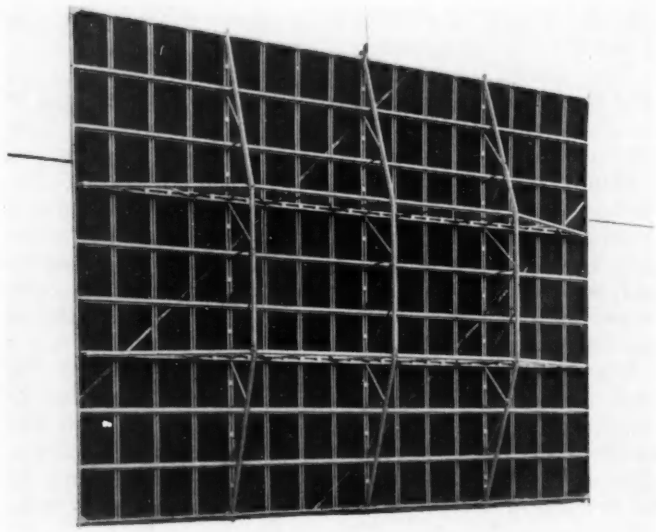


Fig. 8—Surface Unit of Do-X Wing

Rectangular Surface between Spar and Ribs Are Covered by Built-Up Units of This Sort

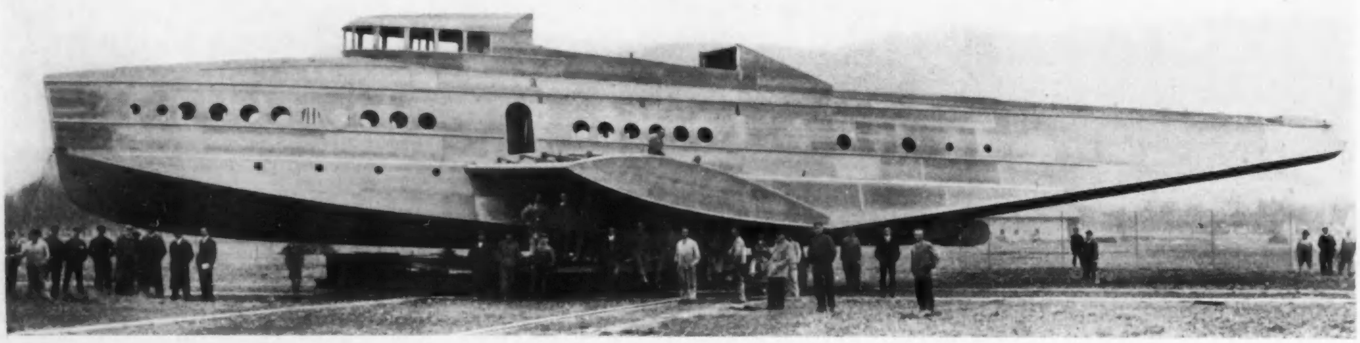


Fig. 9—Hull of the Flying Boat Without Wings

of loading the spar, with sandbags or iron ballast, was not adequate, so it was decided to attach to the joints containers filled with water. This method of applying the stress has proved very satisfactory. The spar was tested with exceptional thoroughness for elastic deformation.

The stresses in the various structural members were ascertained by means of tensometers. Control measurements were made with a Maybach instrument, which was most obligingly put at our disposal by the Deutsche Versuchsantalt für Luftfahrt (German Experimental Institute for Aviation), which also collaborated with us in this test. The measured deflections of the middle spar were charted against calculated deflections at different stages of stress.

The cross members are likewise made mostly of pressed structural shapes. At the point where they are attached to the front spar, it was necessary to build in frames to make it easier for a man to pass through the wing. The spaces formed by the intersections of the three spars with the cross members, which are fitted at intervals of from 2.8 m. (9 ft. 3¾ in.) to 3.6 m. (11 ft. 9¾ in.), are covered with rigid plates of fabric and sheet metal which are called wing-skin units. The portion of the wing behind the rear spar is in the form of an independent sheet. The leading edge of the wing is entirely of metal and is utilized to stiffen the front spar.

One of the wing-skin units is shown in Fig. 8. They are covered partially with sheet metal and partially with fabric. Their manufacture is simple and cheap, and they are easy to fit. They are attached to the main framework by bolts inside the wing. Although the wing profile is not thick, the size of the ship makes the height of the spar so great that it is possible for a man to pass through practically all parts of the wing, even during flight.

Upper Wing and Engine Supports

The upper wing, which is made entirely of metal, enables the engine supports to brace each other rigidly. It worked out to the comparatively high unit weight of 18 kg. per sq. m. (3.687 lb. per sq. ft.). This job has undoubtedly been done unnecessarily well in the endeavor to reduce distortion and vibrations to the minimum. The weight of the upper wing is included in the 15.5-kg. per sq. m. (3.17-lb. per sq. ft.) unit weight given for the whole wing and affects it unfavorably.

The ends of the upper wing between the two outer nacelles are attached slidingly to the middle part, to eliminate inadmissible supplementary stress on the main structure. The engine nacelles are of framework design and they have stream-line cowling and large doors.

A Keelson Strengthens the Hull

The total length of the hull is 40.05 m. (131 ft. 4¾ in.); the breadth, measured over the stumps, is 10.0 m. (32 ft. 9¾ in.); the actual beam is 3.5 m. (10 ft. 8 in.) and the maximum height is 6.4 m. (21 ft. 0 in.). The

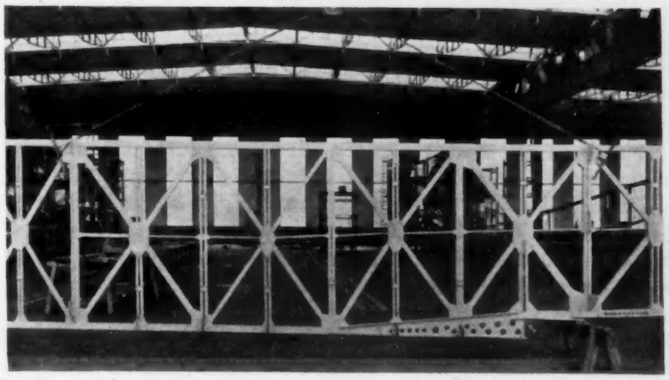


FIG. 10—STRUCTURE OF THE KEELSON

draught of the boat is 0.8 m. (2 ft. 7½ in.) when empty and 1.05 m. (3 ft. 5¼ in.) with a load of 50 metric tons (55 net tons).

The volume of the hull, including the stumps, is 400 cu. m. (14,126 cu. ft.). The volume of the Superwal hull is 100 cu. m. (3531 cu. ft.), and that of the flying boat Romar measures about 75 cu. m. (2649 cu. ft.). Comparing these figures makes it comprehensible that the uninitiated might think that it would be better to remove the wings of the flying ship Do-X and use it as a steamer on Lake Constance.

Fig. 9 is a side view of the hull. The section of the chief frame without stump measures 17.2 sq. m. (185.14 sq. ft.). The spacing of the frames is 0.7 m. (2 ft. 3⅝ in.), there being altogether 58 transverse frames. The keelson, shown in Fig. 10, is an important innovation. It is 23.3 m. (76 ft. 5¼ in.) long, extending from the bow to the end of the stern step, and is 2.12 m. (6 ft. 11½ in.) high at the highest point. It adds much to the

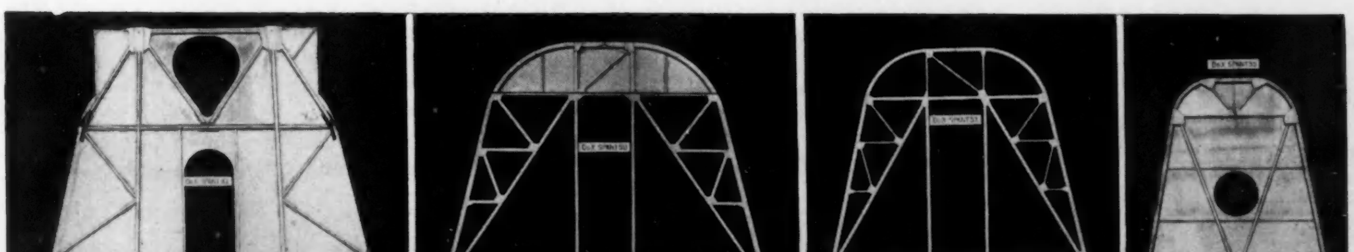


FIG. 11—REPRESENTATIVE FRAMES OF THE DO-X HULL

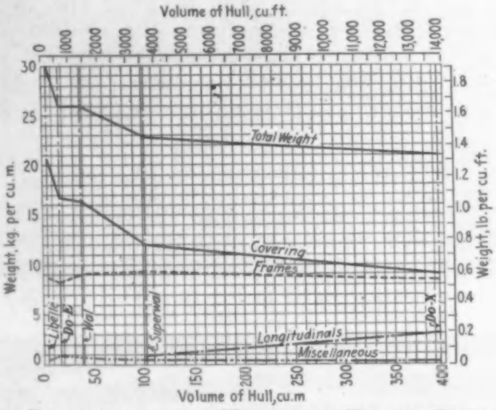


FIG 12—DISTRIBUTION OF WEIGHT IN FLYING-BOAT UNITS

rigidity of the boat. To the right and left of the keelson, at distances of 0.9 m. (2 ft. 11½ in.) and 1.58 m. (5 ft. 3¼ in.) respectively, are fitted bilge keelsons. In combination with the transverse frames, this results in an extremely effective framework. The exceptionally strong sheet-metal plates on the bottom of the boat, which are exposed directly to the sea, are divided by the intersecting transverse frames and longitudinal members into sections of approximately 0.63 sq. m. (6.78 sq. ft.).

Pressed structural shapes were used, as far as possible in consideration of the allowable weight, in making the transverse frames. Fig. 11 shows several of the frames. Detail weights of the frames, the longitudinals, the boat skin and other units were given in the paper[3] which I have mentioned previously. The total and detailed weights of the hulls of the various Dornier flying boats have been plotted in Fig. 12, for comparison, as a function of the corresponding volumes. The tendency of the curves is unmistakable.

The weight necessary for the little Libelle flying boat is 29.9 kg. per cu. m. (1.3666 lb. per cu. ft.) of boat volume; for the well-known Wal high-seas flying boat, 26.2 kg. per cu. m. (1.6356 lb. per cu. ft.); and for the Do-X flying ship, only 21 kg. per cu. m. (1.31103 lb. per cu. ft.). At the same time, the stresses on the material, assuming proportional loads, are considerably lower in the Do-X than in the smaller boats. The flying ship is far better able to support local stresses than are the smaller flying boats; there is far greater danger of local distortion in the latter, because of the thinness of the sheet metal and profile strips used.

Both the hull and the stumps are amply divided by bulkheads. The hull has nine water-tight compartments, and each stump is divided into four compartments. The reserve displacement is exceptionally large. The displacement of the stumps alone amounts to 43.5 cu. m. (1536.179 cu. ft.).

Tail Surfaces and Controls

The general arrangement of the tail surfaces is seen in Fig. 13. The total horizontal tail surface is 53.4 sq. m. (574.791 sq. ft.) and the total area of the vertical tail surfaces is 19 sq. m. (20.451 sq. ft.). All movable planes are counterbalanced by auxiliary planes. The clearance between the elevator and the water-line is 6 m. (18 ft. 8¼ in.). The hull is extended to the rear to protect the rudder against striking the water.

The surfaces are actuated by rods which are supported by rocking levers, and the whole of the linkage is carried by ball-bearings, so that the control is remarkably light. Balancing devices are provided for both longitudinal and lateral trimming. Trimming is effected by altering the angle of incidence of the corresponding balancing planes. This requires no exertion of force and can be done from the pilot's seat by the two small hand-wheels at the side, as shown in Fig. 14. The large hand-wheel in front of these is for actuating the water rudder. Visibility from the pilot's part of the captain's bridge is excellent. The steering-wheel control is normal.

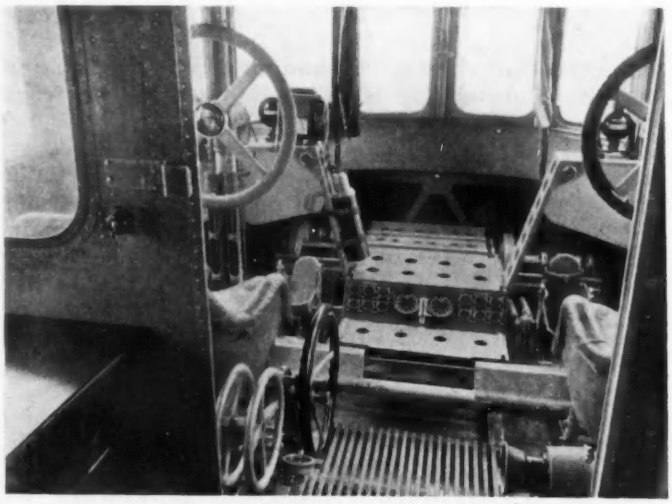


FIG. 14—PILOT-HOUSE

Pilot Is Relieved of Engine Control

Two pairs of the Siemens Jupiter engines with 1:2 reduction, which have been used in the first flying ship, are shown in Fig. 15. The structural parts used in the installation are unusually strong, and much time was devoted to tests of the support. Fig. 16 shows a test in which the stresses in the material resulting from the thrust, torque and the weight of the engine were investigated.

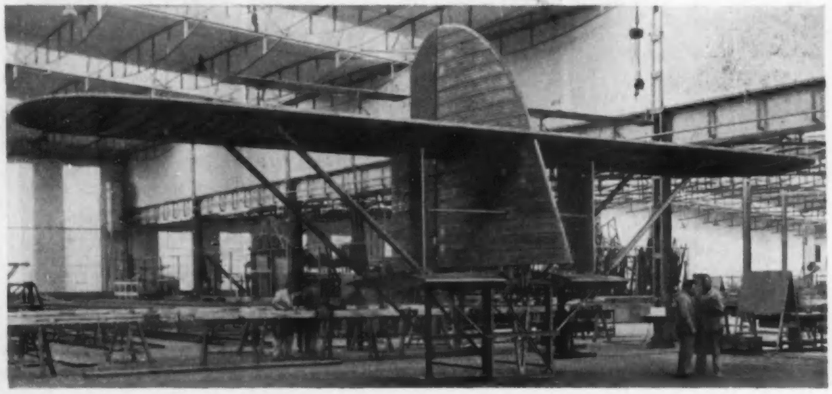


FIG. 13—TAIL SURFACES OF THE DO-X

[3] See *Journal of the Royal Aeronautic Society*, December, 1928, p. 980.

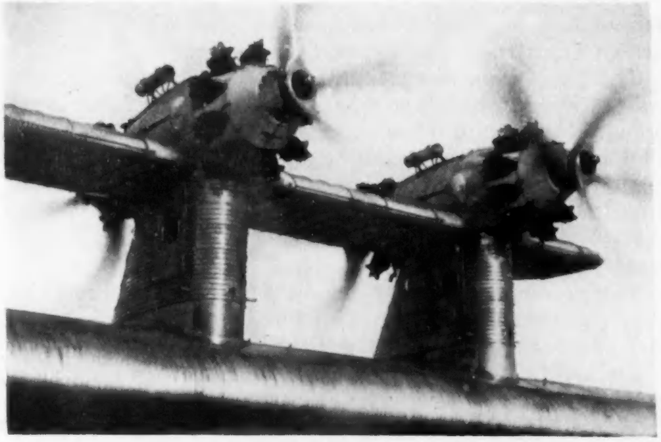


FIG. 15—TWO NACELLES WITH ENGINES
Access to the Nacelles Can Be Had through the Wings during Flight

For the first time in the history of aviation, the pilot of the Do-X flying ship has been relieved of the supervision of the powerplant. He can control all of the engines by two levers which are close beside each other and can be operated by one hand. By operating the two levers separately, it is possible to throttle either the starboard or the port engines, which is very useful when maneuvering on the water. All the engines can be short-circuited at once from the pilot's seat.

We have made concessions to the pilots, who still cling tenaciously to a good assortment of dashboard instruments, and have adorned the otherwise empty pilots' cockpit with two collective revolution counters and an electric indicator apparatus. The latter consists of 12 small lamps, each connected with one of the engines, which are lighted when the corresponding engines are stopped.

Numerous flights have shown that it is not only possible but also very expedient to relieve the pilot of the supervision of the engines.

The starting, remote supervision and the normal stopping of the engines is done from the switch-room, which is shown in Fig. 17. Communication between the switch-room and the engine nacelles is provided by a tunnel passing through the wing. The engines are started by compressed air, which is compressed by a small compressor driven by a gasoline engine, which at the same time drives the generator that provides all of the electric current for the flying ship.

Storing and Handling of Fuel and Oil

In working out the fuel supply, we have kept to that which years of experience has shown to be good. On the deck reserved for fuel and oil are normally four cylindrical containers each of 3000 liters (792.51 gal.) and four of 1000 liters (264.17 gal.) each, making altogether 16,000 liters (4227.2 gal.). The containers, which are directly on the bottom of the boat, are connected with a so-called collecting or distribution tank, from which the fuel is forced by means of pumps into two tanks, each containing 300 liters (79.251 gal.), located in the leading edge of the main wing. To provide the greatest possible certainty of supply, the gasoline can be delivered to the tanks in three different ways: by a wind-driven pump, an electrical pump or an Allweiler hand pump.

The gasoline is transferred from the wing tanks to the carbureters by engine-driven fuel-pumps, the overflow returning to the collecting or distributing tank. On the captain's bridge are glass indicators by which it is possible to control the supply of fuel and oil. All of the piping and connections are easily accessible and can be serviced during flight.

The oil tanks contain altogether 1600 liters (422.672 gal.). They are accommodated in the main wing.

PART 3—ERECTION

The flying ship was built in the workshops of the Dornier Flugzeug Aktiengesellschaft Altenrhein. The work of building was begun Dec. 19, 1927. The launching and the first flight took place on July 12, 1929. The time required for the erection was therefore 570 days. No great practical difficulties were encountered in the

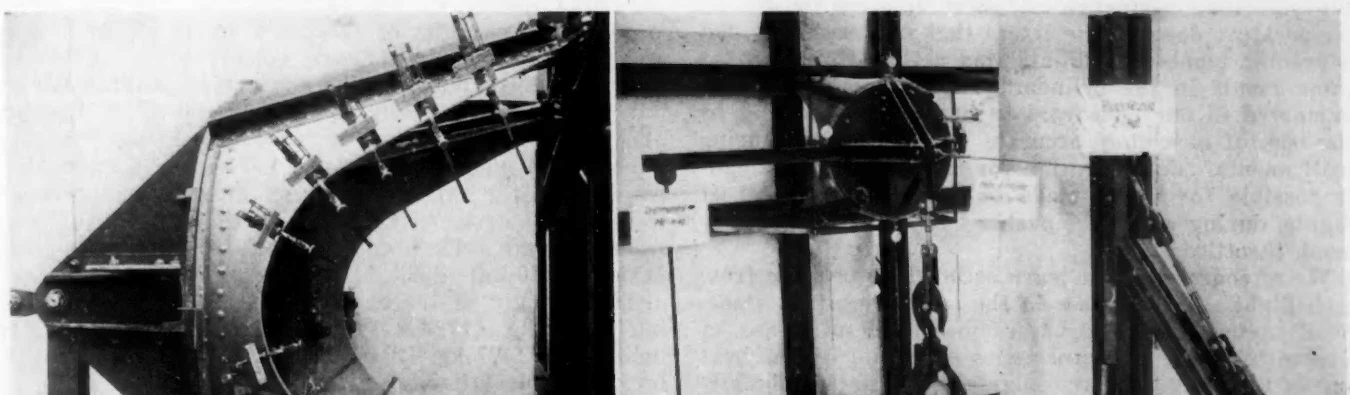


FIG. 16—TESTING AN ENGINE SUPPORT WITH THE STRESSES THAT WOULD BE IMPOSED IN FLIGHT

erection, although a great number of new devices were necessary because the size was so much greater than anything previously known.

Fig. 18 shows the spars during the process of riveting. The erection of the wing was finished in a comparatively short time, because of its new design.

Making the jigs for building the hull frames took a long time. The part to the rear of the stern step was assembled separately from the main body of the hull. Fig. 19 shows the first stages of the erection of the float. The keelson, which is the backbone of the whole boat, is resting on an iron support, and the separately assembled rear portion is fitted on. The framework of the hull is seen in Fig. 20, shortly before the work of covering was begun.

The upper wing was assembled in a unit with the engine nacelles, their supports, the engines, and all the linkage required for actuating them, as shown in Fig. 21, before it was installed on the main wing. The final assembly of the wings, float, tail surfaces and powerplant, including the laying of the controls, took 60 days. Fig. 22 shows this work in progress.

PART 4—THE TRIAL

The trial began early in the morning of July 12, 1929. The launching was accomplished without difficulties. Somewhat lengthy taxying trials on the water were made first. Fig. 23 shows the flying ship while taxying slowly, and Fig. 24 shows it running on the step shortly before taking off. While the flying ship was running on the step with wide-open throttle, during these trials, it took off unexpectedly. Closely following on this unintentional start, a few more short hops were made. The first real flights followed on the next day, and 54 flights have now been made. The two illustrations at the beginning of this paper show the ship over Lake Constance during these tests.

It was found during the first flights that the temperatures of the oil and of some of the cylinders of the rear engines were higher than they should be. Difficulties of that kind were anticipated, as similar symptoms had occurred in the development of each new type. We succeeded comparatively soon in bringing the oil temperature down to the extent that was necessary, but a greater number of flights was needed to obtain the same result in the cylinder temperatures. We were hampered in our endeavors to improve the cooling by the lack of absolutely accurate temperature-measuring instruments. Consideration for the rear engines made it possible for us to make only comparatively short flights, during which the pusher engines had to be very much throttled.

We of course tried to learn as much as possible from each flight. The stresses in the most important structural parts of the wing were measured by means of tensometers; the pressure ratios prevailing in the boat and in the wing were thoroughly investigated; the air-flow around the nacelle and upper wing was received by pitot tubes and the air-flow around the main wing was investigated; and the deflections of the spars were measured optically. The peculiarities of stability of the flying ship were investigated with particular thoroughness, and a series of trimming trials was carried out.

[3] See *Journal of the Royal Aeronautic Society*, December, 1928, p. 980.

I shall limit myself to summarizing the essential facts established by these investigations and the inferences drawn from the tests of the flying ship.

The start was exceptionally good, and action in the water during the start was faultless. The boat came up onto the step in a few seconds, even with heavy loads. The stability on the water was up to expectations, and maneuvering was very simple. Within the first few days, the ship taxied to the buoy under its own power. Conditions of vision were excellent, and landing presented no difficulties.

The powerplant is free from vibration. The average time necessary for starting all 12 engines is 4 to 5 min., and the best time was 3 min.

The flying properties were normal and the flying ship can be flown by even average pilots. The control surfaces are effective and work easily, so that there was no need to install auxiliary mechanism for actuating them.

The elevator was overcompensated at first. The ailerons worked with ease normally, but they required too much effort for great displacement; therefore the leverage and diameter of the hand wheels were increased.

The centralized supervision of the powerplant and the complete release of the pilot from this function proved good.

The deflections and stresses of the structural parts as recorded by the instruments corresponded very closely with the calculations which had been made.

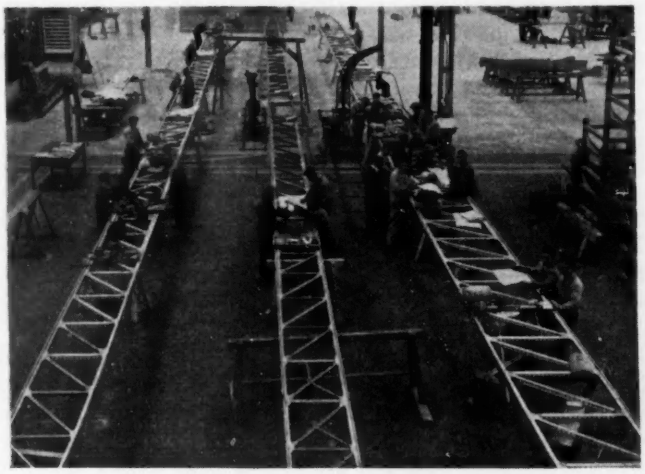
PART 5—THE RESULTS

The design of a new airplane is the embodiment of our hopes and always seems good to us at the moment when we are proceeding to put the project into execution. The measure of success is the extent to which the expectations of the design are fulfilled in practice. It is particularly interesting to investigate the ratio between that which was worked out on paper and what has been in fact accomplished in a venture such as the building of the Do-X flying ship, which for several years was followed by the aeronautical world with great interest and more or less skepticism.

Weights.—In my previously mentioned 1928 London paper[3], I made statements regarding the expected weights of the units of the Do-X flying ship. These weights are listed in the first column of the Table 1. The second column contains the actual weights as of July 31, 1929. The weights for fuel and oil equipment and instruments, as given in the first column, were reduced to a common basis for comparison with other airplanes. In the third column are given corresponding weights proportioned from the actual weights of the second column. The total difference in weights on this basis is 2189 kg. (4829 lb.) or 8.8 per cent. If the additional weight of the engines and propellers, amounting to 782 kg. (1724 lb.), is subtracted, a total weight increase of 1407 kg. (3102 lb.) or 5.6 per cent remains for the airplane itself.

Taking Off.—In Fig. 25 the taking-off times of a great number of flights are plotted against the respective flying weights. All the starts were made on Lake Constance, which is 400 m. (1312 ft.) above sea level. The results of these take-offs and flights must be evaluated in consideration of the fact that normal Siemens-Jupiter engines with a compression ratio of 5.3:1 were used.

The contract conditions for the flying ship, laid down



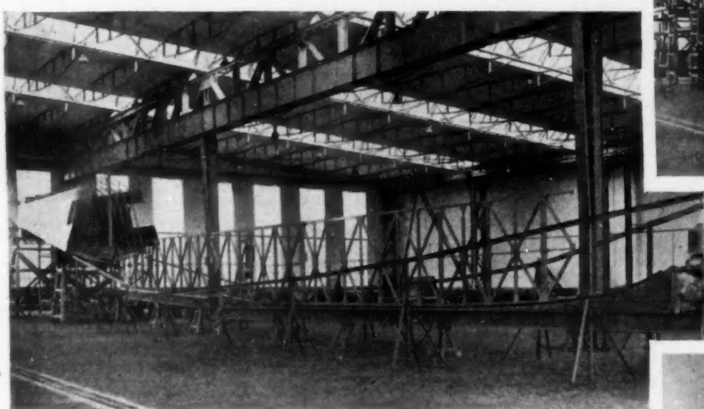


Fig. 18—Riveting the Spars

Fig. 19—An Early Stage of Hull Assembly

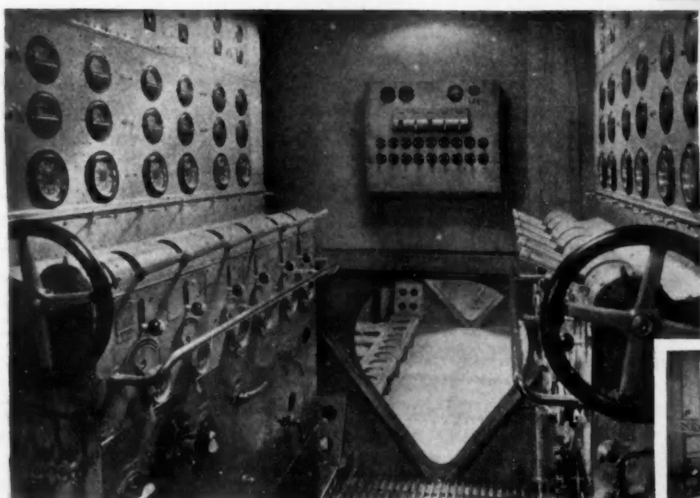
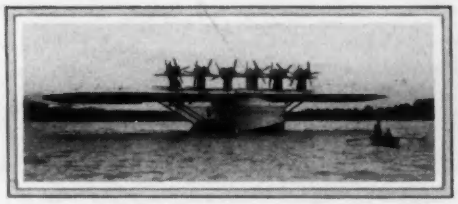


Fig. 17—Engine-Control Room



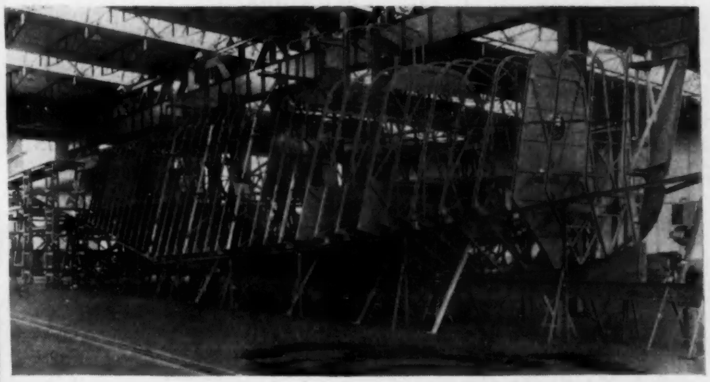


Fig. 20—Hull Framed Ready for Covering

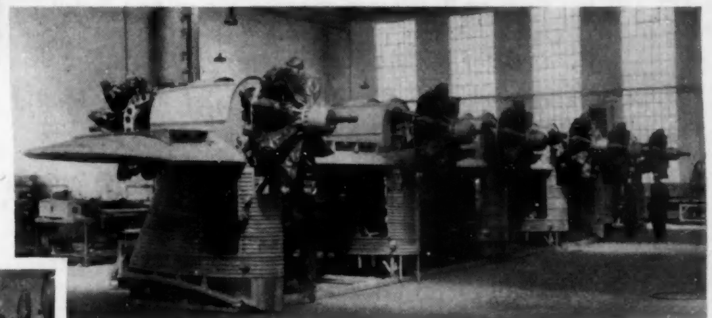


Fig. 21—Assembling the Upper Wing and Powerplant

Fig. 22—Final Assembly of Flying Boat

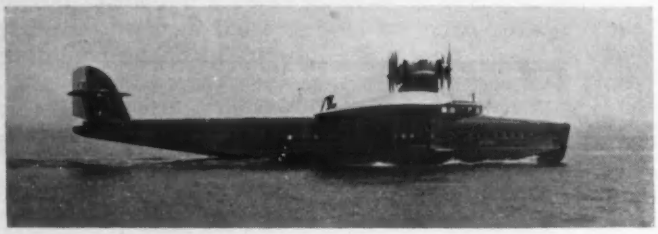


FIG. 23—TAXYING AT LOW SPEED

in 1927, guaranteed a pay-load of 20 metric tons (22 net tons). This would make the taking-off weight 48,000 kg. (105,821 lb.) with the estimated structural weight. Fig. 25 shows that the flying ship would require 65 sec. to take off from Lake Constance with no wind under these conditions. Reduced to sea-level conditions, the take-off would require 55 sec.

Flying Speed.—The contract specified that the maximum speed of the flying ship should not be less than 200 km. per hr. (124.27 m.p.h.) with a tolerance of 5 per cent. A speed of 211 km. per hr. (131.11 m.p.h.) was actually attained with uncowled engines at an altitude of 420 m. (1378 ft.). This is equivalent to 214 km. per hr. (132.97 m.p.h.) at normal atmospheric pressure. No doubt the speed can be increased by suitably cowling the engines. A single set of wooden propellers has been used for all flights so far made; a further increase in speed will be made possible by the use of other propellers, especially of metal propellers. With the engines throttled to 1850 r.p.m., the flying speed is 175 km. per hr. (108.74 m.p.h.) at an altitude of 420 meters (1378 ft.).

Flying Radius

The relation between flying radius and useful load is indicated in Fig. 26. The range of the Do-X flying ship was investigated on the basis of an average consumption of gasoline and oil amounting to 270 gm. (0.595 lb.) per hp-hr. and assuming that all engines are throttled to the same extent. The abscissas of the diagram show the distances in kilometers and the ordinates the useful loads in kilograms. The sloping graph lines denote the taking-off weights of the flying ship and range from 45 to 52 metric tons (49.6 to 57.3 net tons). The weight with equipment was taken as 28,000 kg. (61,729 lb.), in accordance with Table 1. To arrive at the actual useful load, we must subtract the weight

FIG. 24—RUNNING ON THE STEP

of the supplementary marine equipment, the crew and the fittings of the passengers' rooms. We have done this on the diagram for the first two by drawing tare lines parallel to the abscissas allowing for supplementary marine equipment a constant of 500 kg. (1102 lb.) and for the weight of the crew a constant of 1000 kg. (2205 lb.). The furniture and similar equipment needed for short flights were assumed to be considerably more than for long distances, because of the greater number of passengers. This equipment is represented in the diagram by a line which indicates 2000 kg. (4409 lb.), for zero distance, and itself becomes zero for a distance of 4000 km. (2485 miles).

The vertical distances between this outfit-line, which is placed above the horizontal tare lines, and the sloping lines denoting the different loading conditions of

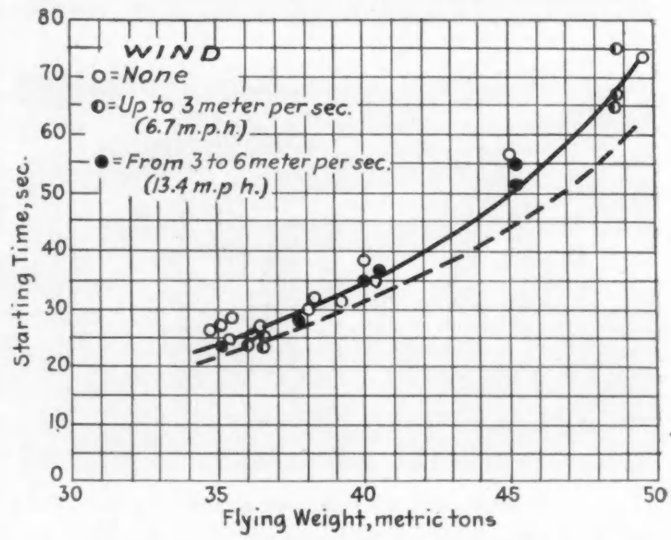


FIG. 25—TAKING-OFF TIME WITH VARIOUS TOTAL WEIGHTS
The Full-Line Curve Is the Average of Tests at Lake Constance, Which Has an Altitude of 400 M. (1312 Ft.) The Dotted Curve Represents the Time That Would Be Required at Sea-Level

the flying ship indicates the useful-load capacities in each case. For instance, the useful load for a distance of 1000 km. (621 miles) and a taking-off weight of 45 metric tons (49.5 net tons) is 7600 kg. (16,755 lb.) or 76 passengers, 100 kg. (220 lb.) being allowed for each passenger. If a wind reserve of 50 per cent is desired on the distance of 1000 km. (621 miles), it would be necessary to start with approximately 48 metric tons (52.9 net tons). For a flight of 2000 km. (1243 miles), starting with 48 metric tons (52.9 net tons), the pay load amounts to 4900 kg. (10,803 lb.). A wind reserve of 30 per cent would necessitate taking off with 52 metric tons (57.3 net tons).

The greatest distance that can be flown without a stop, according to the diagram, is about 3600 km. (2237 miles). For really long-distance flights the flying ship would have to be fitted with more economical engines. Reducing the average consumption of gasoline and oil from 270 gm. (0.595 lb.) to 220 gm. (0.485 lb.) per hp-hr. would increase the radius of flight from 3600 km. (2237 miles) to 4400 km. (2734 miles).

A considerable increase in the flying range will be attained when we are successful in installing a clutch or neutral between the propeller and the engine. It will then be possible, for the sake of flying economically, to

cut out completely one or more engines separately without the resistance or loss of power resulting from propellers that are either stationary or cause the dead engines to rotate.

PART 6—ECONOMIC POSSIBILITIES

The limit of continuous flight for which the flying ship in its present form could be utilized under favorable meteorological conditions, carrying the necessary reserve of gasoline and oil, is about 2200 km. (1367 miles). Fueled and equipped for this distance, with 30 per cent wind reserve and a pay-load of 2000 kg. (4409 lb.), the taking-off weight would amount to about 50,000 kg. (110,231 lb.) and the starting time to about 65 sec. This radius of flight of 2200 km. (1367 miles) seems very modest and requires some explanation in comparison with the present long-distance records, which have reached nearly 8000 km. (4971 miles).

The superlatively excellent flying achievements of Franco, Lindbergh, Köhl, Costes and many others have deservedly won the admiration of the whole world. They have without doubt given a new impulse to airplane construction. We must, however, realize that these great achievements were only possible by overtaxing both the human and the material elements to a degree exceeding that which is ordinarily possible and practically permissible.

How great is the gap between the long-distance record and the contemporary achievements of practical air transport may be illustrated from the following:

On October 4, 1929, Joachim von Schroeder, of the Deutsche Luft Hansa Aktien Gesellschaft, gave a paper before the Technical Literary Society in Berlin on Experiences of Post Express Flights to Siberia and Spain. In his very interesting remarks Mr. von Schroeder states that, taking into consideration the practical development of the present day, one could reckon on a load of 150 kg. (330.7 lb.) or at the most 200 kg. (440.9 lb.) for the flight of 1250 kg. (777 miles) from Berlin to Seville, with an intermediate landing at Marseilles. The flights on which his statements were based were carried out with a land machine of the most modern design, fitted with a 500-hp. Hornet engine and having a speed of 170 km. per hr. (105.6 m.p.h.).

The statement of Mr. von Schroeder indicates that the present practical limit of the flying range of commercial planes is approximately 1250 km. (777 miles), because a useful load of less than 150 kg. (330.7 lb.) to 200 kg. (440.9 lb.) would not warrant the use of a plane from an economic point of view.

The long-distance record is 8000 km. (4971 miles) and the longest

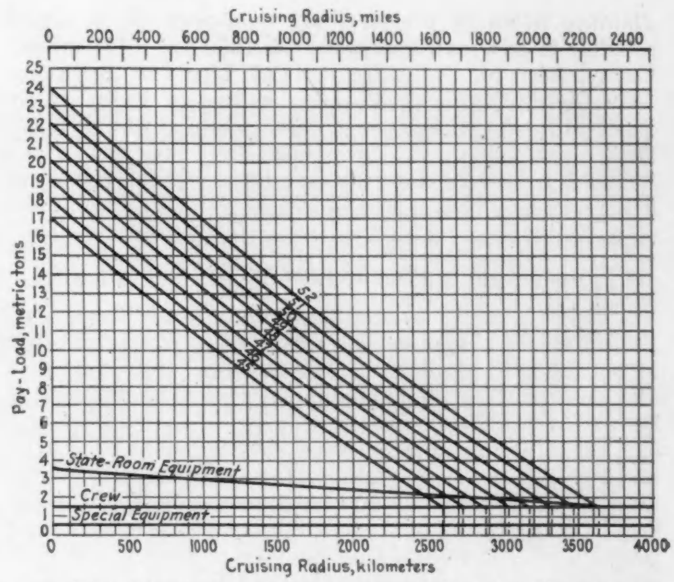


FIG. 26—CRUISING RADIUS WITH VARIOUS LOADS

Figures on the Curves Indicate the Total Weight of the Loaded Ship, in Metric Tons. One Metric Ton Is Equivalent to 2,204.62 Lb.

TABLE 1—COMPARISON OF CALCULATED AND ACTUAL WEIGHTS

	Predicted Weight Kg. (Lb.)	Actual Weight Kg. (Lb.)	Actual Weight Corrected for Comparison Kg. (Lb.)	Difference in Weight Kg. (Lb.)	Difference in Weight Per Cent
Wings and Struts	7,475.8 (16,481.4)	7,559.4 (16,665.6)	7,559.4 (16,665.6)	+83.6 (184.2)	+1.1
Tail Surfaces	728.7 (1,606.5)	878.2 (1,936.1)	878.2 (1,936.1)	+149.5 (329.6)	+20.6
Controls	322.5 (711.0)	363.5 (801.4)	363.5 (801.4)	+41.0 (90.4)	+12.7
Hull	7,235.3 (15,951.1)	8,314.0 (18,329.2)	8,314.0 (18,329.2)	+1,078.7 (2,378.1)	+14.9
Engine Nascelles and Supports	1,072.7 (2,364.9)	1,147.2 (2,529.1)	1,147.2 (2,529.1)	+74.5 (164.2)	+6.9
Paint	350.0 (771.6)	350.0 (771.6)	350.0 (771.6)		
Engines	4,721.0 (10,408.0)	5,121.6 (11,291.2)	5,121.6 (11,291.2)	+400.6 (883.2)	+8.5
Exhaust Manifolds	39.0 (86.0)	39.0 (86.0)	39.0 (86.0)		
Propellers and Hubs	720.0 (1,587.3)	1,101.9 (2,429.2)	1,101.9 (2,429.2)	+381.9 (841.9)	+53.0
Engine Controls	350.0 (771.6)	226.9 (500.2)	226.9 (500.2)	−123.1 (271.4)	−35.3
Fuel Tanks	919.0 (2,026.0)	1,236.4 (2,725.8)	1,002.4 (2,209.9)	+83.4 (183.9)	+9.1
Oil Tanks	274.5 (605.1)	359.6 (792.8)	300.5 (662.5)	+26.0 (57.3)	+9.5
Oil and Fuel Piping	120.0 (264.6)	120.0 (264.6)	120.0 (264.6)		
Powerplant Instruments	130.0 (286.6)	278.2 (613.3)	109.5 (241.4)	−20.5 (45.2)	−15.8
Flight Instruments	6.9 (15.2)	13.9 (30.6)	6.9 (15.2)		
Navigation Instruments	1.5 (3.3)	36.0 (79.4)	1.6 (3.5)		
General Equipment	30.4 (67.2)	80.0 (176.4)	30.4 (67.2)		
Auxiliary Operating-Equipment	194.8 (429.5)	417.5 (920.4)	188.0 (414.5)	−6.8 (15.0)	−0.35
Marine-Operating-Equipment	250.0 (551.2)	270.7 (596.8)	270.7 (596.8)	+20.7 (45.6)	+8.3
Total	24,942.1 (54,987.9)	27,914.0 (61,539.8)	27,131.7 (59,815.1)	2,189.5 (4,827.2)	

distance flown in practical air transport—it is almost possible to add mail transport—is 1250 km. (777 miles). Comparison of the statement of Mr. von Schroeder with the 2200-km. (1367-mile) radius of flight of the Do-X indicates a doubling of the practical flying range. We must take into consideration that Mr. von Schroeder was considering a land airplane; nevertheless the flying boat has doubled the radius of flight and increased the useful load in the ratio of 10 to 1.

Profitable Routes of Less Than 1000 Miles

I believe that it is possible to employ the flying ship profitably for distances of from 1000 to 1500 km. (621 to 932 miles) and, in exceptional cases, in traveling to and fro for very short distances. The possibilities of its utilization in European waters are many and various. Its possibilities for places where fogs are encountered frequently are of particular interest. Because of its very large dimensions, the flying ship can taxi and drift far more safely than previous flying boats in a rough sea, and it can therefore land many miles outside the port of destination, if need be, and either proceed under its own power or be towed into port.

In Fig. 27 is given a selection of routes suitable for the flying ship, beginning with short distances and extending to 2000 km. (1243 miles). The graph shows the flying time and pay-loads for the respective routes and further the number of passengers to be carried in each case, each passenger being reckoned at 100 kg. (220 lb.). The maximum number of passengers that can be comfortably accommodated is reckoned at 100. If the useful load amounts to more than 10,000 kg. (22,046 lb.), the difference can be made up with freight or mail. The diagram was based on the assumption that the taking-off weight should amount to 45,000 kg. (99,208 lb.) without wind reserve. The taking-off weight would therefore be increased in practice by the weight of the reserve gasoline and oil to be carried. A reserve of 30 per cent for a flying distance of 1800 km. (1118 miles, would bring the weight up to 49.5 metric tons (54.6 net tons). The reserve of gasoline and oil naturally is much less for shorter distances.

The chart shows that a useful load of 12,000 kg. (26,455 lb.) can be carried between Buenos Aires and Montevideo, and that this load corresponds to 100 passengers and 2000 kg. (4409 lb.) of mail or freight. Between Hamburg and Southampton or Marseilles and Algiers, a useful load of 9000 kg. (19,842 lb.) or 90 passengers can be carried.

We have thoroughly investigated the operating cost of the flying ship, on the basis of completely amortizing the airplane in 5000 hr. and engines in 1000 hr. of flying. The cost of oil and gasoline has been reckoned at 59 pfennigs per kilogram (about 39 cents per gal.) and the insurance at 16 per cent per year on the value of the flying ship when new. Considering all costs with the exception of interest on the invested capital, we have arrived at an estimate of 15 to 18 Reichsmarks per kilometer (about \$5.78 to \$6.94 per mile), according to the distance to be flown without intermediate landings. The ton-kilometer cost is about 2 Reichsmarks (about 76 cents per ton-mile) for a route of 1000 km. (621 miles) and a yearly flying total of 75,000 km. (46,603 miles). When the distance traveled falls to 500 km. (311 miles) and the yearly total flown to 55,000 km. (34,175 miles) the ton-kilometer cost drops to 1.50 Reichsmarks (about 57 cents per ton-mile).

PART 7—THE OUTLOOK

The graph in Fig. 28 shows the increase in load capacity of airplanes during the period from 1916 to 1929. During the 10 years from 1918 to 1928, the load increased from 3700 kg. (8157 lb.) to 7500 kg. (16,535 lb.); only 100 per cent. The Do-X flying ship has brought the load in one step from 7500 kg. (16,535 lb.) up to 22,000 kg. (48,502 lb.), tripling the capacity.

In view of this diagram, is it possible to doubt that we shall reach loads of 100 metric tons (110.5 net tons) or even more in another 10 years? I think not. The air will present no more unknown difficulties.

The building of the Do-X flying ship has proved that increased dimensions do not affect the structural weight in the unfavorable way previously assumed by many writers. The static problems and especially the dimensioning of the structural members are simplified by the increase of the stresses. Everything becomes more convenient, more accessible and cheaper. The proportion of equipment, instruments, spare parts, crew and devices for service and safety to the total weight of the bare plane decreases rapidly as the dimensions increase.

Development of the engine alone does not seem to keep pace with the progress in airplane building. I believe that the flying ship will give a fresh impulse in this direction. Civil aviation may not be able for the time being to exploit the full loading capacity of this new means of trans-

(*Concluded on p. 575*)

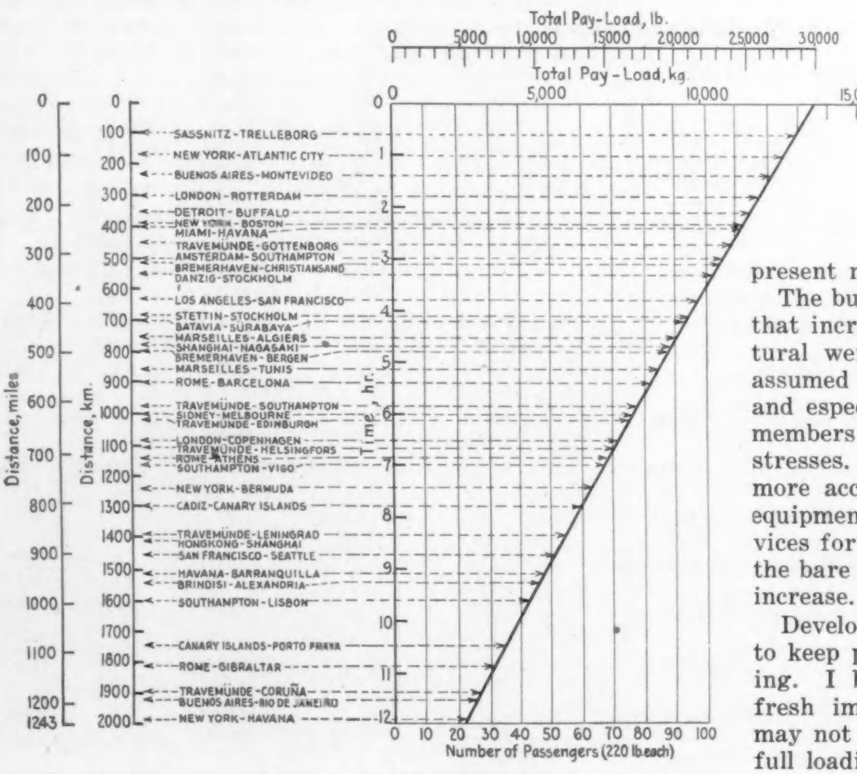


FIG. 27—LOADS THAT CAN BE CARRIED ON VARIOUS ROUTES

Past Adventures and Future Prospects of the Metalclad Airship

By Ralph H. Upson[1]

Annual Meeting Paper — *Illustrated with* Photographs and Drawings

OPINIONS, favorable and otherwise, that have been expressed by various authorities in this Country and abroad regarding the possibilities of the metalclad airship are quoted by the author, with appropriate comments based on his experience of approximately nine years in the design and construction of the ZMC-2, the world's first successful all-metal dirigible. Following this introduction the author proceeds to discuss the likelihood of metalclad airships of larger capacity being developed, what the limits to this development are and the reasons for the conclusions drawn. A table comparing the ZMC-2 with two hypothetical airships of three times its size and presenting data on volume, length, diameter, skin thickness, maximum pressure, speed, weight and lift supplements the text.

The extensive preparations that were made before the test flights and the great care exercised during them were described by one of the discussers who also related some of his experiences on the flight from Detroit to Lakehurst, N. J. The commencement of design for a 100-ton airship to be flown at 100 m.p.h. was announced by another speaker. As compared with the ZMC-2, this new craft will have a gross lift that is 17 times as great.

"WEREN'T YOU *thrilled* when the ZMC-2 actually flew?" was the question most frequently asked at the official trials. To a group of engineers who appreciate that no big job was ever done single-handed and that every step in a consistently planned development has its own importance, the answer should be obvious and need not concern us here. The point of immediate interest is the inference that mere flight is still, to many people, the criterion of a successful aircraft. I should be curious to know whether any of these people, when buying a new car, ask "Does it run?" If so, they are probably those who go to a football game to find out who will win. Others, to be sure, are apparently more interested in the score and in collecting various statistics such as yardage gained, number of kicks and the like. Finally, we find those who are interested in the game itself. To serve the last type of interest is the only excuse for this paper, because, in the case of the first metalclad airship, the general result is already well established and all the principal statistics are available from other sources[2]. To be specific, I feel that this paper should serve mainly as a framework on which to hang discussion. To bring it uptodate, we shall open the proceedings with a review of the various claims that have been made as to the merits of the construction, both pro and con, and then consider them in the light of the facts thus far known.

Alleged Disadvantages

Starting with the "con" items, it is surprising how many and ingenious were the reasons against building an airship of metal:

(1) A metalclad airship can be built big but not small

[1] M.S.A.E.—Aeronautic engineer, Red Bank, N. J

[2] See The Journal, February, 1926, p. 117; also *Mechanical Engineering*, Decemebr, 1929, p. 905.

(2) It can be built small but not big; this is more recent
(3) The skin would be too tight
(4) The ship would be too heavy
(5) It would be too flexible to hold together
(6) It would be too stiff to accommodate itself to temperature changes
(7) Changes in pressure and stress would develop destructive vibrations
(8) Engine noise and vibration would be greatly accentuated
(9) Gas would leak through the seams and through the pores of the metal
(10) The skin would corrode very quickly
(11) It would have insufficient strength against tearing
(12) It could not resist shocks
(13) It would be ruined if anyone stepped on it
(14) The ship would be a target for lightning and static
(15) Its operation would be too dependent on pressure
(16) The short, fat shape would make too much drag
(17) It would also make the ship uncontrollable
(18) The single gas compartment would not be feasible
(19) The multiple fins would work against one another
(20) Facilities for inspection would be inadequate
(21) Repairs would be difficult
(22) The riveting would be too difficult and expensive
(23) It would be impossible to make a smooth job
(24) The gas would heat up excessively in the sun
(25) The stresses would be impossible to calculate
(26) Attaching the skin to the frame would be very difficult
(27) The finished ship could not be inflated
(28) It could not be deflated without collapse
(29) It would be wrecked if a wrench were dropped on it, if a bird flew against it, if it collided with the hangar or met with any similar mishap

Alleged Advantages

The following advance claims are taken literally from the summary given in my 1926 Annual Meeting Paper entitled Metalclad Rigid Airship Development[3] where the progress made prior to January, 1926, was said to give promise of these results:

(1) A substantial airship that is
 (a) Proof against static sparks
 (b) Durable in weather
 (c) Determinate in stresses
(2) A ship of unprecedented efficiency
 (a) Structurally
 (b) Aerodynamically
 (c) Practically
(3) A fireproof structure in which hydrogen gas can be used both for buoyancy and reserve fuel as safely as gasoline, or in which helium may be used with maximum economy and effect
(4) An economical aircraft whose first cost in materials is low, as well as its cost of upkeep and renewals
(5) A long-range vehicle that besides needing no right of way is independent of hangars, except for "drydock" purposes
(6) A commercial carrier destined some day to carry substantially all first-class passengers, all mail and all express on the longer routes over land and sea

[3] See THE JOURNAL, February, 1926, p. 125.

[4] See THE JOURNAL, February, 1926, p. 117.

On counting the vote the No's would seem to have it by a substantial majority; but considerable has happened in the last four years. Although the general features of the design had already been worked out at that time[4], calculations and laboratory tests are intangible things at best. To make wild assertions about something that does not exist is easy, but now we have something real to talk about.

The ZMC-2 and Further Development

That the ZMC-2 is too small for any practical commercial efficiency must be admitted, as it always has been. Direct conclusions are still dangerous, but that airship is an enormous step ahead of nothing. It is a workable metalclad airship, the first of its kind, and is now in regular operation for Naval training purposes. It employs the same general principles of design and construction that are proposed for much longer airships. Still more important, it met all the performance requirements laid down for it, most of them by a considerable margin, and in doing so exceeded in some respects the best that has been obtained from any other airship of similar size. Although this is no direct proof of what can be done with larger sizes, it is at least a substantial reason for taking seriously any further development in a consistently planned and directed engineering program. Even as the ZMC-2 was not undertaken without practically establishing its success in advance, a larger airship need not be started without similar assurance, especially with the much better foundation now available on which analysis can be based.

Unfortunately, mere time spent on a problem is no guarantee of its successful solution and often results in a loss of much needed perspective. Thus some of the greatest aids to success of this last job were the criticisms that were hurled at it. All were taken seriously, though not too seriously, in trying to work out the best compromise that the conditions warranted. Now seems to be the time for a new crop of objections, which will be sincerely welcomed; but first let us consider the status of some of the old ones and see if we can reach a point of departure where we are all speaking the same language. Intelligent criticism must depend on one or more of the following conditions:

(1) Possession by one party of knowledge that the other lacks
(2) A difference in the exercise of personal judgment
(3) A difference of definition or fundamental conception of the subject under discussion

Limits of Size

For example, take objection (1) that a metalclad airship can be built big but not small. Nearly 10 years ago, when I was first studying the possibilities of this construction, one of my engineering acquaintances in Germany told me that he and his associates had seriously considered the possibility of metal covering but had come to the conclusion that it would be feasible only in very large sizes. Later the chief engineer of another big airship organization, discussing the same subject, set 10,000,000 cu. ft. as his estimate of the minimum size. At that time I was working on a tentative design of 1,000,000 cu. ft., which, to play safe, was shortly raised to 1,600,000 cu. ft., still rather small; but further study and experiment convinced us that a much smaller size was feasible, and 200,000 cu. ft. was

finally decided upon for the first unit. Thus a discrepancy of about 50 to 1 between the estimate of our foreign contemporary, who is unquestionably a very competent engineer, and our plans existed. How then is such an enormous difference to be explained?

To begin with, the engineer in question apparently conceived the metal as a mere covering, like his fabric cover, contributing little or nothing to the strength of the airship as a whole. Even so, an extra weight per unit of surface becomes naturally a less percentage of the total lift as the size is increased; hence the importance of large size in such a case, especially for the long cigar-shaped hulls then in vogue. His reasoning was correct as far as his own knowledge and experience went, and one could hardly expect more of any human being. The new and presumably unconsidered items, which made up most of the difference, were

(1) A close, rigid structural union between the framing and the skin
(2) A circular section, instead of polygonal, with an arrangement of structure enabling the skin to take its share of the lift stresses
(3) A simple automatic pressure-feed, keeping the skin in a condition to carry an important part of the aerodynamic stresses with the minimum of local reinforcements
(4) A type of seam enabling the lifting gas to be held directly by the skin
(5) Attainment of satisfactory speed and control with a hull two to three times more compact, as measured by fineness ratio, than rigid airship hulls previously in use

As an established fact, this has now become recognized engineering knowledge, as witness the following: A celebrated lighter-than-air authority recently congratulated me on the success of the ship, but could not help adding, half to himself, "But of course it *would* be a success in such a *small* size." He was entirely right, although I should have expressed the same thought more like this, "A small ship, properly designed *as* a small ship, might be expected to succeed, but not a *large* ship designed as a small one." In other words, for the very reason that the features of the ZMC-2 are suited to its small size, they are unsuited for the most part to a much larger size. Qualitatively, the above principles still hold for a large ship of radically different purpose, but quantitatively the difference is as great as between a ferryboat and an ocean liner.

Controlling Considerations for Small Sizes

With respect to the metalclad construction, special considerations imposed by the small size of the ZMC-2 were mainly as follows:

(1) The difficulty of obtaining and handling skin material thinner than a certain gage
(2) The comparatively large ratio of surface to volume
(3) The small volume of gas, totaling less than one of the compartments of the Graf Zeppelin
(4) The small powerplant, totaling less than one of the engines of the Graf Zeppelin
(5) Frame girders too small and too light to serve as passageways or walkways
(6) The favorable effect of the small scale on the relative structural weight

Results of the above considerations as exemplified on the ZMC-2 were

(1) The extremely compact hull
(2) The avoidance of heavy protective coatings
(3) The single gas compartment
(4) The concentration of powerplant and useful load in a single outside car
(5) The lack of access to certain parts in flight
(6) The very large margin of strength, most of which is in the skin

The last is expressed not only in the direct load-factor, which undoubtedly averages higher than that of any airship previously built, but also a much greater range of pressure, about 10 times the conventional allowance for rigid airships. This variation of structural efficiency with size, which is quantitatively inherent in any structure, represents one of the few advantages of very small airships, but even this is tempered by the relatively greater accelerations and sensitivity to gusts.

Stepping Up in Size

That a large airship cannot be arrived at by any simple process of proportion from a small one may be sufficiently obvious but, for the amusement it may afford, I will show by just this process how true is the claim that the form of metalclad construction represented by the ZMC-2 *cannot* be successfully applied to much larger sizes. For this sole purpose, equations or curves dealing with long series of variables are not needed. Instead we may simply imagine an airship similar to the ZMC-2 but of three times the linear dimensions, including pressure heads and everything but the thickness of structural parts and skin. The latter is assumed of uniform gage and the same load factor except for a weather-resisting layer of 0.002 in. The speed is increased enough to keep the dynamic head of

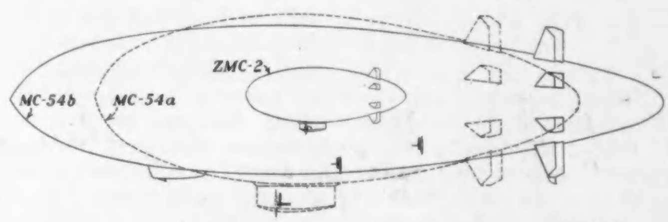


TABLE 1—COMPARISON OF THREE METALCLAD AIRSHIPS

	ZMC-2	MC-54a	MC-54b
Volume, cu. ft.	200,000	5,400,000	5,400,000
Hull Surface, sq. ft.	19,500	175,000	195,000
Length, ft.	150	450	600
Diameter, ft.	53	159	140
Average Skin Thickness, in.	0.009	0.065	0.015
Maximum Pressure, in. of water[5]	4.0	12.0	3.0
Maximum Speed, m.p.h.	69	120	100
Total Horsepower	440	14,000	4,800[a]
Weights			
Skin and Seams, lb.	2,900	180,000	49,000[b]
Frame and Ribs, lb.	1,400	30,000	55,000
Powerplant and Connections, lb.	1,600	55,000	24,000
Cars and Passages, lb.	1,100	10,000	20,000
Fins and Controls, lb.	700	30,000	18,000
Internal Diaphragms, lb.	800	7,000	13,000
Miscellaneous, lb.	300	2,000	4,000
Total Weight Empty, lb.	8,800	314,000	183,000
Useful Load,[6] lb.	4,800	53,000	184,000
Gross Lift at 0.068, lb.	13,600	367,000	367,000
Useful Load in Terms of Gross Lift, per cent	35	14	50

[5] Difference between inside and outside of skin at bottom of maximum section.
[6] Including tanks, radio and passenger accommodations.
[a] For clean efficient design.
[b] Including the weight of the protective film, estimated at 2000 lb.

air proportional to the static head of gas. This hypothetical airship, designated MC-54a, will then be compared with another metalclad of the same size, MC-54b, which is proportioned and arranged with some regard for its size and inherent capabilities. The results, all in roughly approximate figures, for hydrogen inflation are presented in Table 1.

Some Questions Raised

As between the two large ships, the most striking difference is clearly in respect to the internal pressure carried and the weight of the skin. The great advantage of the lighter skin very logically brings up the following questions and answers:

(1) Why will not a further gain in the reduction of the skin to a mere cover, as on a conventional rigid airship, be possible?

Many factors are involved which would take us beyond the scope of this paper, but the most fundamental is contained in the following proposition: Consider two hollow cylinders, of the same material and carrying the same bending moment; in one of them the wall is kept under initial tension by a proper internal pressure to cover the desired range of bending stress; in the other the bending stress is carried directly by compression members. For the proportions represented in an airship hull, it can readily be shown that the pressure cylinder is structurally the more efficient.

(2) If that is the case, why is the MC-54a, with the higher pressure, under such disadvantage?

Because the pressure in this case and the weight of skin to resist it are out of proportion to the actual stresses that would otherwise be carried.

(3) Then why not carry at least enough pressure to practically eliminate the compression members?

This would make everything, including the shape itself, dependent on pressure, which is exactly the principle of the non-rigid airship. Although made of fabric, a generally poor material for structural purposes, a good non-rigid airship is not at all to be despised. In small sizes and at low speeds, where the structural factor is favorable, it can carry a very fair useful load, and at rest has a pressure range from about 0.5 to 2.5 in. although without much reserve strength and durability. If a large size non-rigid airship could be made of duralumin, the relative structural efficiency would be increased more than four times. Entirely aside from construction difficulties, however, such an airship would hardly be practical because it would depend on unnatural mechanical sources for maintaining at all times the necessary pressure between extremely narrow limits. In the early days I considered the possibilities of flexible panels and various take-up devices to permit a reasonable variation in shape but soon decided on the following requirements as fundamental: (*a*) enough framing must be used to ensure that the general shape of the hull remain rigidly non-deformable at all times, (*b*) adequate strength must be provided to carry all static loads without pressure and (*c*) minimum internal-pressure in flight must be capable of continuous support by the speed of flight itself.

The proposition of having the design conform to some previously recognized *type* was not even thought of. Classification might be made on the basis of the National Advisory Committee for Aeronautics nomenclature, which defines a rigid airship as one whose form is maintained by a rigid structure. My own use of the word has been not as designating a type, but, in the ordinary English meaning, as resisting change of form.

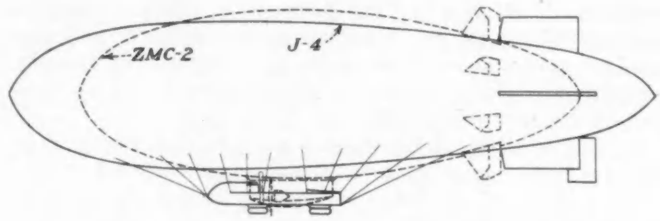


TABLE 2—COMPARISON OF SMALL METALCLAD AIRSHIP WITH A NON-RIGID OF EQUAL SIZE

	ZMC-2	J-4
Volume, cu. ft.	200,000	200,000
Engine Power, b.hp.	400	300
Engine Speed, r.p.m.	1,800	1,400
Maximum Speed, m.p.h.	70	58
Useful Load, lb.[7]	2,000	4,000
Speed of Ascent and Descent, ft. per min.	1,500	1,200
Turning-Circle Radius, ft.	200	400
Loss of Lift, lb. per day	10	18
Approximate Cost	$300,000	$100,000

[7] For helium inflation and about 10 per cent of air in balloonet.

In the latter respect, the ZMC-2 in actual operation is certainly the strongest and *most* rigid airship that was ever built. This is of purely practical importance in establishing the speed and airworthiness qualities that will be essential to any widespread commercial use of airships. Those interested in more erudite distinctions of type will probably find that the metalclad cannot be classified except as an entirely new type, but it makes no difference what it is called.

Proved Advantages of Metal Construction

By the same token, the word metal, per se, possesses no particular magic that justifies its indiscriminate use. True, metal seems to be increasingly used in most lines; but clothes, for example, have gone exactly the other way since knighthood was in flower. So, coming back to the alleged advantages and disadvantages of the metalclad airship, the advantages claimed have not yet been fully realized in this demonstration ship, but I know of nothing yet which disproves any of them. Some of the real troubles have been obviously disposed of, and those of the metal-hazard kind have somehow lost their appeal in the cold clear light of reality.

Experience with the ZMC-2 to date (See Table 2) seems to have definitely established its superiority in the following respects:

(1) Low material-cost, compared with either goldbeaters' skin or rubberized fabric
(2) Low upkeep cost to date
(3) Strength and general rigidity
  (*a*) High pressure, 14 in. of water in full-size section
  (*b*) Low pressure, slightly negative
  (*c*) Construction load, 14 men supported by skin
(4) Maneuverability
  (*a*) Quick reaction of controls
  (*b*) Short turning
  (*c*) Rate of ascent and descent
(5) Speed capabilities, actual speed better than for any other airship of its size without even approaching the structural limit
(6) Aerodynamic lift

Lack of time and of occasion have thus far prevented any practical demonstration of fireproof and weatherproof qualities and behavior in a bad storm. To date, the ship has *not* collided with the hangar, and, to the

best of my knowledge, no bird has tried to attack it in any direct way. On the trip to Lakehurst some misguided hunter shot an 0.45 bullet through the hull, making holes that were easily patched.

Shortcomings of the ZMC-2

Although, as mentioned above, the ZMC2 easily met all contract requirements, I was personally a little disappointed in the following items:

(1) *Streamlining.*—It appears possible now that the tail should have been a little finer and the drag was also increased by lack of refinement around the car, otherwise the speed would have been still better.

(2) *Dependence on Pressure.*—When full of gas, or in any case under power, the fundamental requirements as originally chosen are apparently fulfilled, but the air system as installed makes some pressure necessary when at rest with much air in the balloonets. The remedy is clearly to let the air take its own level instead of forcing it into restricted containers.

(3) *Stability in Rough Air.*—The righting moment for a given angle of yaw or pitch is the best of any airship that I know of, but the small mass makes for relatively large accelerations, and due to the short arm the damping moment suffers. An automatic damping arrangement, devised for the purpose, has so far not been tried.

(4) *Ground Handling.*—From a desire to play safe on the possibility of injurious vibration, the propellers were put needlessly far from the hull; on the other hand, the ground clearance should have been greater to suit the Navy practice of warming-up in the open.

(5) *Useful Load.*—Construction changes in the skin, balloonet and various car items have added upward of 700 lb. to the weight empty, and the use of helium instead of hydrogen has reduced the useful load by a good 1200 lb. more; however, plenty of useful load remains.

(6) *Cost of Construction.*—The great bulk of total cost has accrued from

- (*a*) Development proper, chargeable to a whole program of construction
- (*b*) Business expenditures, not directly relevant to the technical development
- (*c*) Design proper, chargeable to a specific unit
- (*d*) Actual construction.

Drawing the line between (*a*) and (*c*) is a matter of judgment in each case. Although at first they are both very substantial items, in the long run their economic importance lies in what they save rather than in what they cost. Thus item (*d*) is the one that is of the most direct interest as affecting future prospects. Of this, by far the greater part is labor and its attendant overhead, which has been clearly excessive in the case of the ZMC-2. More broadly, this problem of labor cost is perhaps the most fundamentally serious of all confronting further development. Let us see where it stands.

Construction Methods

From the very inception of the metalclad idea, the development has been approached largely from a construction standpoint. Materials were chosen which were generally available and in common use and, to avoid needless experimentation, conventional methods and shop equipment were assumed for the first airship wherever at all feasible. The most important exception to the latter was the problem of riveting the skin, which may be appreciated from the fact that there are about 3,000,000 tiny rivets in the skin alone of the ZMC-2. Hence, before proceeding to any real details of the airship design, the prerequisite of an automatic riveting-machine was provided for. As this required the attention of a machine-design specialist, an effort was first made to interest some established manufacturer in the development of such a machine but without success. In the meantime I had been on the lookout for an individual of the proper qualifications and finally picked E. J. Hill, who developed the present riveting machine and during construction was put in charge of the job as a whole. Other special equipment for the shop included an arc machine for pattern layouts, surface-treating apparatus, jigs and various improved tools.

The design of frame members was particularly conditioned upon shop considerations. The fins, and originally the car, were largely an adaptation from Stout Metal Airplane practice. The vertical method of assembly, with skin work always in advance of the framing, was early decided upon, and the design of course proceeded on that assumption. Even the method of inflation had to be predetermined and definitely provided for from the beginning. Riveting two separately completed halves of the hull together was an extra problem for this airship, arising later when psychological considerations made doing all the construction in a small hangar at Detroit necessary.

In general and as far as they went, the methods adopted have proved sound and, aside from a few obvious mistakes, are perhaps all that were justified for an experimental construction. But further and larger units will not be economically worthwhile without a very substantial lowering of the construction cost. For the designer to blame the shop man for lack of ingenuity, or for the shop man to call the designer impractical, is of no use. Generally speaking, improvements in construction economy are to be had neither by a slavish conformity to a predetermined design nor by expecting the design staff to accommodate itself exclusively to standard sheet-metal practice, airplane practice, plumbers' practice or whatever the current style may be. Like most other things, the only way to get very far is to take full advantage of the best possibilities on both sides. This has not yet been done.

Summary

The first metalclad airship, though small, is a definite success. As far as fundamental principles are concerned, a ship can now be built of sufficient size for limited commercial use. But it will involve entirely new arrangement and proportions, suited to the size and purpose, and it will be economically available only with considerable improvement in the facility of construction. How far this will go depends on design as well as on construction methods; but, most of all, it depends on the larger engineering job of coordinating the two.

As this is an engineering paper, it has not been concerned with general business or other outside requirements. From a business standpoint especially much remains to be done, which, nevertheless, I believe can be done. To back the original enterprise took plenty of real courage, but to carry on from here is largely a matter of common sense.

THE DISCUSSION

CHAIRMAN C. B. FRITSCHE[8]:—Four years ago this month, in the General Motors Building, Ralph H. Upson, formerly with the Goodyear Tire & Rubber Co. as chief engineer of the aeronautical department, and later chief engineer of the Aircraft Development Corp., presented a paper at the Annual Meeting of the Society in which he described the experiments, then in process, that later resulted in the metalclad airship ZMC-2, the ship that in the intervening years has been designed, built, tested, delivered, accepted and paid for.

One of the interesting things is that every promise that Mr. Upson and his associates made to the Congressional committees that were called upon to investigate this experiment, every promise made in 1926, was fulfilled in August and September of last year with a safe margin over contract requirements. One example is the fact that, after making due allowance for the weight included in structure for unforeseen items, the useful load exceeded contract requirements by 127 lb. I do not believe that any airplane builder has ever built a new type airplane weighing even one-half of 6 tons gross weight and upon completion has found his product that close to his weight estimate, an estimate made four years prior to actual flight. This record constitutes a challenge to airplane builders for exact, mathematical, scientific attainment.

The contributions to the building of this ship by the Bureau of Aeronautics of the Navy, by the Army Air Corps, by the Bureau of Standards and the National Advisory Committee for Aeronautics were extremely helpful, and I would state that one of the reasons why the ship flew was the fact that those associated with its design and construction tried to keep an open mind toward criticisms, on the theory that those who had the patience to criticize were friendly toward the ship. Experience proved that the critics contributed much of value to its success.

Test Pilot Relates Experience

CAPT. WILLIAM E. KEPNER[9], U. S. A.:—I do not know that I can, or should, add anything to what Mr. Upson has to say about the construction or the design of the ship. My job was not construction or design. I consider that I was very fortunate to have been the test pilot of the little airship. I learned considerable and think it will mean much to me in the future.

With regard to the slow take-off in the first flight; that is often commented upon. I like to explain that this was no fault of the ship. The program, as decided upon by the Naval Board before the flight, was to the effect that we should proceed very carefully. Of course, I was responsible and my plan was to carry this out. But it had to be submitted to them, and they thoroughly agreed that we should proceed as we did.

The airship had been tried out in the hangar and was perfectly safe as a free balloon. The idea of taking off with no forward speed at all was that the airship would be high enough, when we started the engines, so that if any defect in control developed we could still handle the airship as a free balloon and return it safely to the field over which we were at that time. You observed that several bags of sand were thrown out. We did not want to make the ship so light that in going up it would be too light to land coming back, in the event that we had to land immediately for any reason. We took it off just about as near equilibrium as we could and then let out the weight gradually until we arrived at an altitude that was safe. Actually, now that I look back over the flight, we might just as well have stayed in the air then and finished all the test flying, provided we could have had enough gasoline to have landed at Lakehurst. I do not know if the man previously commented upon would have been out there with a shotgun on the way over the Pennsylvania mountains or not.

With regard to maneuvering out of the hangar and the care that was taken going in and out of the hangar: An airship's first flight is made largely through the efforts of the man who designs the ship and the preparation that is made on the ground. When we started to collect the maneuvering crew for this particular airship, we had plenty of volunteers. Fortunately, Mr. Fritsche was able to secure some soldiers and we organized men in charge of different landing lines and gave them a long drill; we told the soldiers exactly how we planned to make the flight and then went out and did it that way. Much difficulty is experienced with a green crew like that. For psychological reasons, the maneuver must be carried out exactly as planned. If anything is wrong, changing the plans presents difficulties, as every individual man expects the maneuver to be done a certain way and when a change is made a little argument arises in each man's mind before he agrees to put all his efforts into it. We were committed to a plan that had to be followed out, regardless of any trouble that came up, and we were almost forced to follow the original plan. Therefore, we always had plenty of men. If half of them pulled in the worst sort of a gust or drag we would still be safe. I never got the ship back into the hangar that I did not feel that I should give a sigh of relief over the maneuver rather than over the flying.

The First Test Flights

As far as the first flight is concerned, my main effort and endeavor was to get the airship off the ground, fly it around, bring it back, put in on the ground and take it into the hangar so that the men who were to maneuver the airship would have confidence in its ability to hold together and in the fact that it was an airship and that people generally would forget all about it. When it got off the front page of the newspapers, I intended to test it. Actually, at the end of the first flight everybody attached more importance to what I said then than to what I said later about the excellent performance on other flights. I said nothing at first except that it had gone into the air, that the thrust could be delivered safely at a speed that assured control and that the ship had done everything I had expected it to do, which meant practically nothing.

On the next flight, which was the following day, I did nothing but play with the controls and move the airship around. I dipped it, turned it and one thing and another. On that occasion I was selling the ship to myself. When I came in I was perfectly satisfied that, with the exception of some of the very high requirements, no difficulty would be experienced in making the test. On the third flight we got the ZMC-2 down over the river in front of Detroit and over Belle Isle. Some

[8] A.S.A.E.—Vice-president, Aircraft Development Corp., Detroit.
[9] Wright Field, Dayton, Ohio.

of you probably saw it. The reason for this was that on the following day we were taking the airship to Cleveland. I wanted to see how it acted in the vicinity of a city. Around buildings and different sorts of pavements, mixtures of water, all sorts of air currents are encountered. These are very rough on an airship; that is, it does not fly through the air as smoothly and cleanly as it does on a clouded day, or in the evening, or at night. The ZMC-2 was brought down here in Detroit for that express purpose and not to show off on that trip in the least.

On the following day we took off for Cleveland to a strange airport. The little airship had been in the air only a very little time, but we had so much confidence in it that even with the short time flying, which was very short as airship time goes, we were perfectly willing to take it into the hands of a green crew that had never landed an airship; probably some of them had never seen one except perhaps at a distance in the air.

Mr. Upson went along. As I recall it, he took hold of the controls and he must have had a lot of confidence in the airship, too. I thought that he intended to try out over Lake Erie all the tests the airship was designed to make before it ever got there. All of his expectations, I think, were justified. Perhaps he was disappointed in some of the performance. I do not know what he expected, but I am sure that the airship world in general has been very happy over the results of these tests.

I do not know what the Navy thinks. I have not communicated with any of the officers since I left the airship at Lakehurst; but I do know, from my contacts with them in the past, that they look at airships very much the same as I do, as something to be proved over a series of tests. Over the life of an airship alone can its entire worth be proved.

One thing that bothered me considerably in the beginning was whether the airship would hold gas. I have been in the game for about 10 years, but I must say that I was considerably worried. That the airship held gas so well seemed remarkable to me, almost phenomenal. But this bears out the contentions of the men who built the ZMC-2 and those who had to do with the production of the job generally.

Flying the ZMC-2 to Lakehurst

On the flight east from here we took off in the evening about 10 o'clock with enough gasoline for about 20 hr. of flying at a cruising speed that we considered safe. The ship had not yet run its high-speed test and we decided to fly at about 50 to 52 m.p.h. on the way to Lakehurst. We were running one speed test of 6 hr. and after that we might run at any speed we wanted, provided the air was such that we could arrive there in the time limit of our gasoline supply. We ran the 6 hr. at 52 m.p.h. and, as the airship was running along so smoothly, we allowed it to run continuously at that speed for some time more. Part of this time we were bucking about a 30-mile wind. At least, during 1 hr. one of my checks showed we had made 20 miles ground distance. The difference between the air speed of the ZMC-2 and the ground speed might be expected to be due to the wind. We could not make very much speed.

The valleys were filled with fog, the sky had become clouded over and was thickening up. We were pretty late at the first point where we had decided we would refuel. Incidentally, as a preliminary a few days before we left Gross Ile, we practised the art of picking up fuel in the air. We did not have another ZMC-2, as the Robin had when it made its long flight; only one of Henry Ford's best of the last year's vintage was out there, an ordinary roadster. Two men from the Aircraft Development Corp. ran the automobile along on the ground and we dropped a rope over and hooked up our load of gasoline and then pulled it aboard. We did that three times on two different days just to see if we could do it with the airship running straight ahead and then crabbing sideways. Our idea was that, if we had to buck wind and needed fuel, we could take fuel on the fly anywhere in the mountains. I really think that it was a shame we did not have to take some so that we could prove our ability to do so.

I believe that when dirigibles are used extensively this method of picking up loads from the ground will be utilized, not for fuel alone but also for a great many other things. No shock whatever was apparent when we picked up the load. The slack is taken out of the rope and the load swings around in the air a little bit, of course, depending on the direction of the flight. To pick the load up and move away with it is very easy. We were not statically light at that, either; we picked up the load purposely when we were heavy to see what the effect would be.

During the night we made very poor speed on that flight. When the sky got a little bit light, I came down so that we were just clearing the tops of the trees and there we were able to make fair headway. But when I got to Lakehurst everybody thought I had been drinking all the way over because my eyes were about as red as a robin's breast, a bloodshot condition from being exposed to the wind. That is how closely I had to watch our flight to avoid hitting the trees. Down near the ground comparatively no air was flowing, and by following certain valleys that ran nearly parallel to our course we were able to make almost air-speed time from there on in and after 13 hr. we arrived at Lakehurst.

The Bullet Hole in the Metal Covering

Some time, while we were down below the tops of the hills, we received a bullet from one of the friends over there who perhaps thought we were revenue inspectors or something of the sort. I had no knowledge that any accident had occurred to the ship or that there had been any hole or any shooting or anything else going on. Afterward, Lieutenant Dugan said that he recalled a time when a gun had been fired at us near Easton, Pa. If that is the case, those holes were in that airship for several hours before we arrived at Lakehurst. When we landed, the holes were discovered by a member of the maneuvering party.

I admit that men, upon seeing the hole in the airship, would reason that a rivet had given way or that some structural part had broken, but this was not the case. Actually, we found a hole in one of the seams of the ship where the rivets joined the two sections together. This was a perfectly round hole, about the size of a 0.45 caliber bullet, with an indentation inward on one side and on the other side between two seams an elongated hole such as a flattened bullet would make as it was going out. That is rather good proof that a break in the skin will not cause it to tear any farther and also that the riveting is strong enough to stand the shock of a blow such as a bullet would put on it in making such a hole.

In our high-speed test, running out over the water south of New York City and off the shore, a speed of approximately 64 m.p.h., as near as I could estimate it, was very easy to maintain. That was well above the limit required, and everybody was satisfied. We were then running at 1740 r.p.m. On the way back from the coast, over the New Jersey pines, we ran the engines up to 1925 r.p.m. Incidentally, I think that whoever designed those propellers ought to be complimented on his work. The design of a propeller that would allow the engine to run at the calculated speed must be pretty nearly perfect.

E. P. WARNER[10]:—I was in a position where I had to watch the evolution of this airship rather closely and pay rather close attention to the reaction of public opinion toward it. Although I think it would hardly be fair to say, and I will not say, that anticipation among experts on the subject that the ship would fail was general, some certainly felt that way, and certainly a great many of us, and I will have to include myself among that number, preferred to play perfectly safe by making no prophesy and not committing ourselves. Now that the airship has been built and has flown, although it is perhaps too much to say that the skeptics have been put to rout, and Mr. Upson has been very frank in explaining the difficulties that exist and upon which work remains to be done, it certainly is not too early to say, and this was clearest to those who watched it most thoroughly throughout, that the ZMC-2 has been a very great achievement. No one could possibly have been in touch with it without having the greatest admiration for the work that was done in the development of the theory and the practical application of that theory and in the practical building of the airship. No one could have seen that work from the time the contract was signed, and in fact during the preliminary stages of experiment until the test flights were made or a considerable part of it, without having the greatest admiration for Mr. Upson, Captain Kepner and last, but not least, for Mr. Fritsche, who never wavered to the slightest degree in his belief that the ship would be a complete success.

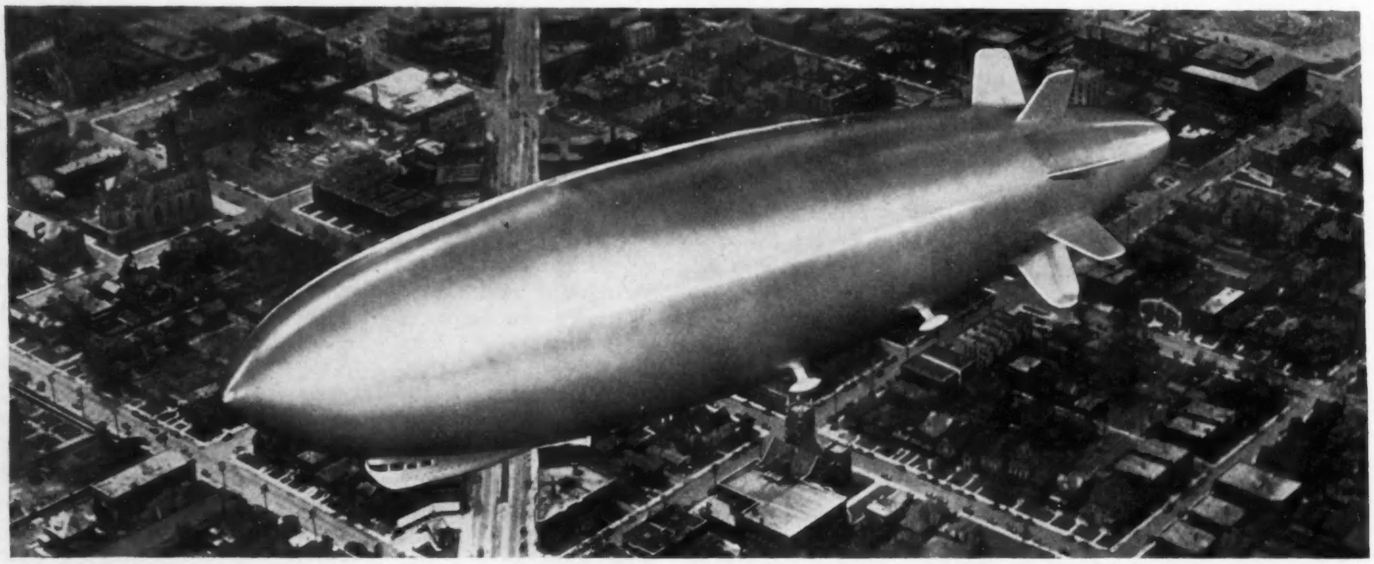
[10] M.S.A.E.—Editor, *Aviation*, New York City.

A 100-Ton Airship Flying at 100 M.P.H.

CHAIRMAN FRITSCHE:—I presume that most of you are interested in the question, Where do we go from here? and I presume also most of you have read a preliminary announcement to the effect that the design of a 100-ton ship with a speed of 100 m.p.h. is now in process. In lifting capacity this airship will be something like 17 times as great as the ZMC-2. A speed of 100 m.p.h. is entirely practical with the metal cover; at least we believe so. Our wind-tunnel tests have not been made as yet, but our general weight estimates and performance data compiled indicate a useful load with helium inflation in the neighborhood of 35 per cent of the gross lift. If our speed were reduced to that of the Los Angeles, our useful load would be about 40 per cent. The thickness of skin of a ship of this size will be greatest in the mid-section where the hoop tension is greater. The hull covering will be approximately 0.018 in. thick, tapering down to as low as 0.012 or 0.013 in. at each end.

The actual design of an airship of this size will take at least a year before construction can begin. For whom we shall build it, we do not know. As Mr. Upson remembers, when investigation was started about nine years ago, we did not know for whom we would build the first metalclad airship, but we finally found a customer. In this development stage the only market may be the Government, and, that being true, I do not think we need to apologize or feel any hesitancy in asking the Government to appropriate the money, because the ratio of expenditure by our Government for airplane development compared to that for airship development has been $100 to $1.

To visualize where the airplane would be if that ratio had been reversed would be interesting. We believe, in the light of present design, materials and fuels, that the airship possesses qualifications far superior to either the airplane or the flying-boat for long-distance overseas travel, and while the flights that have been made by airplane over the Atlantic and elsewhere have demonstrated a very high degree of courage, unusual skill and excellent dependability of engines, yet in each instance payload has equalled zero. On the other hand,



THE PROPOSED 100-TON AIRSHIP HAVING A SPEED OF 100 M.P.H.

we have witnessed the Graf Zeppelin, which is small, as airships will grow to be, carry a substantial payload around the world.

Transatlantic Airship and Airplane Flights

Out of eight attempts to fly the Atlantic by airship, seven have been successful, and the eighth was not a failure but was an excellent demonstration of the ability of an airship with four of its five engines out of commission to maneuver back to a French port in the face of adverse winds, accomplish a safe landing, have temporary repairs made, go to its own hangar for permanent repairs and then continue the flight across the Atlantic. What would have happened to a large flying-boat caught in a storm over the Mediterranean with four of its five engines out of commission? Undoubtedly another fatal accident. Yet most of the newspapers, when the Graf Zeppelin turned back to France on the attempt that did not succeed, failed to differentiate between engine failure and airship success, and I think that in all fairness this distinction should be borne in mind.

On the other hand, out of 36 attempts to fly the North Atlantic by airplane, only 9 have been successful.

I believe that the cause of the airship is one deserving of peculiar consideration on the part of men possessing engineering minds and who are not influenced in their conclusions by the waves of popular opinion that sweep first one day in one direction and the next day in another direction. Anyone who has approached the subject from a scientific standpoint knows for a fact that the airplane does not increase in efficiency with size to any appreciable extent, whereas the airship does, because, as the airship increases in size, the horsepower increases only as the square of the linear dimensions, whereas the lift increases approximately as the cube of the linear dimensions. On the other hand, if we double the size of the airplane, we double its resistance and the engine power and fuel required, so that the useful-load factor is practically a straight-line function.

With these facts before us, if we are sincerely interested in conquering the broad expanse of the Atlantic and Pacific, the use of public funds to bring about a development that will accomplish this, we believe is well justified. This is the objective of those engaged in the development of the metalclad airship.

The Do-X Flying Ships

(*Concluded from p. 566*)

port. Let us utilize a few hundred or even a few thousand kilograms of the superfluous load capacity either for increasing the weight and at the same time the reliability of the engines and diminishing their fuel consumption or else for increasing the strength of the hull. This might appear to be taking a step backwards, but in reality it would be making a start in the direction of converting civil aviation into a serious business.

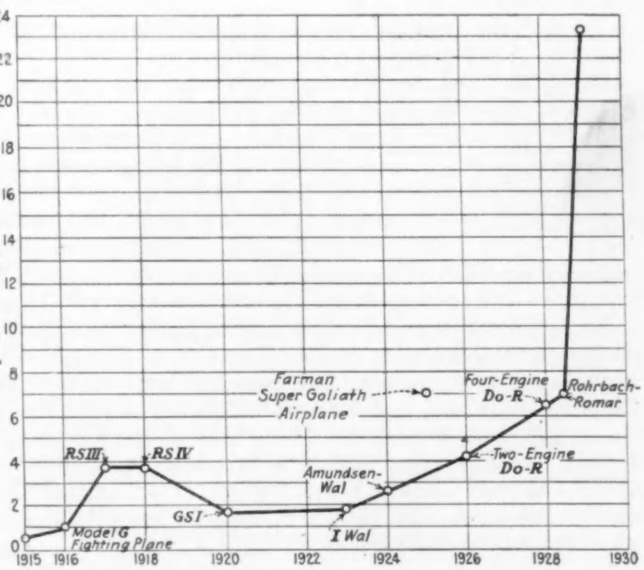


FIG. 28—HOW LOAD CAPACITIES ARE GROWING

Aviation is now suffering from a general impression that we are farther advanced than we really are. Inferences are based on top performances, and far more is demanded of the airplane, the engine and the human element than they can reasonably give. Retrenchment must ensue. The increase in dimensions opens the way to cut down the demands upon material and the human element, and at the same time to remain in the realm of that which is profitable.

When I look back upon the difficulties which we encountered in undertaking to build the flying ship, I must confess that the practical difficulties were relatively small in comparison with the financial and moral obstacles which had to be overcome. The popular remark that we were taking too great a leap caused me much trouble; and, after the successful outcome, there came the new comment that the flying ship was in advance of the needs of the time.

The Do-X flying ship would never have been built had I not been absolutely convinced that we were dealing with a consistent development which, backed by our 15 years of experience and all the resources of modern research and science, involved no greater risk than any other great creative work of engineering.

It is clear to me that we must still travel a long and thorny road to secure for the new means of transport its place under the sun; but I know that, the feat having been achieved, the demand exists. Not the demand for what we now call air transport, which is for the most part artificially created and kept alive by subsidies, but the real demand arising from necessity and from adequately satisfying economic needs.

Inspection Methods Used for Aircraft Engines and Parts

By Charles S. Cain[1]

Los Angeles Aeronautic Meeting Paper

ADEQUATE maintenance of aircraft is mandatory, according to the author, the term "maintenance" being considered applicable to the craft and airports and covering the work on the craft and on the engine and its accessories from the time the engine is installed until it is removed from the plane. A special job-number is given each engine-installation, and all work performed on the engine and its accessories is charged to a maintenance account.

The routine inspections that determine the time for making minor repairs and major overhauls are described by the author. Inspections include the gasoline, lubrication, ignition and storage-battery charging systems, current from the last being used for radio, cabin and landing lights. Engine controls—such as the throttle, spark and altitude levers, and in some cases a carbureter-heater control—are inspected next, and then the temperature-gage system which indicates to the pilot the temperature of the oil in a radial engine or of the water in a water-cooled engine. Inspection of the exhaust system and pipes comes next, then the starting mechanism.

Before work is done on any of the parts, their condition is ascertained during the regular trip-inspection. It is stated that aircraft time is reckoned in hours of flying time and, according to the author, the inspection system is built up in units of 16-hr. flights. By this system it is possible to lay out definite things to be done at the end of inspections at 16, 32, 48, 64 and 96-hr. flight periods.

The methods of inspection are described in detail for the various gasoline, lubrication and other systems, as well as for the various parts. The author states that the planning for all kinds of maintenance is an essential, a fact often not fully realized by operators, and that cooperation by the expert maintenance mechanics employed is likewise a necessity. Suggestions are also made as to the possibility of making the various aircraft parts more accessible, thus making maintenance easier and engine replacement more speedy.

In the discussion following the paper, comments on the practice with regard to military planes at San Diego, Cal., are made by Com. L. B. Richardson, of the United States Navy, and the results of some special inspections in regard to finding specific troubles are stated by the author, one of the major troubles being wear caused by dirt.

FEW VERY complicated pieces of machinery run with the regularity that characterizes the operation of Transcontinental Air Transport Co. aircraft engines. The reasons that engine failures are now old-fashioned occurrences are the wealth of knowledge and experience that lie behind present design, the encouragement of research that the market for good engines provides, modern methods of manufacture, the unheralded work of an army of engineers that has developed engines which perform faultlessly if properly used, the consideration given by the modern pilot to the engine during flight in that he favors his engine in every particular, and the fact that, after the engine has had a definite amount of service, which varies among the different operating companies, it is completely overhauled. Engine overhauls by our company result in engines that would be approved by a factory inspector, no matter how strict he is. We buy a good engine, treat it right while it is being flown, and then rebuild it so that it is as good as new.

Adequate Maintenance Is Mandatory

As an airport term, "maintenance" covers the work on the engine and its accessories from the time it is installed until it is removed from a plane. A special job-number is given an engine installation; all work performed on the engine and attached parts is then charged to a maintenance account until the engine is removed.

All repairs affecting the engine mount are charged to the plane; but, in routine inspection, the engine mount is considered as an engine accessory and is inspected when the engine is inspected because it is deemed the logical part on which to begin an engine inspection.

Inspections include the gasoline, lubrication, ignition and storage-battery charging-systems, current from the last being used for radio, cabin and landing lights. Engine controls—such as the throttle, spark and altitude levers and, in some cases, a carbureter-heater control—are inspected next, and then the temperature-gage system which indicates to the pilot the temperature of the oil in a radial engine or of the water in a water-cooled engine. Inspection of the exhaust system and pipes comes next, then the starting mechanism, and this completes the inspection of the accessories.

But before work is done on any of the parts, the condition of these parts must be ascertained. This is done at the regular trip-inspection, and the inspection at our Glendale terminal is, I believe, absolutely air-tight. If the work that is ordered from the office is conscientiously done, engine failures are almost impossible, about the only chance being failure of an engine part due to breakage, and this is remote in the engines the air-transport companies are using.

Method of Reckoning Aircraft Age

Aircraft time is reckoned in hours of flying time; so we have built up an inspection system using as units 16-hr. flights. By this system it is possible to lay out definite things to be done at the end of inspections at 16, 32, 48, 64 and 96 hr. of flight. We have an office

[1] Field manager, Transcontinental Air Transport, Inc., Wichita, Kan.

file that shows the flying time of the plane, engine, and propeller. They start out with no time charged and, after 16 hr., require a certain amount of work. Records are kept so that the next time that plane comes in it gets a 32-hr. inspection, and so on. Then the cycle is repeated for the 16 and for the 32-hr. periods; but, the next time, the plane gets a 96-hr. quality-inspection, which is what we call "the works" from beginning to end. Then the inspection cycle begins again.

To assure the coverage of every certain thing to be done, we have a card showing all the items on the engine and plane to be inspected after 96 hr., in a form similar to that used by the Los Angeles Police Department. A piece of celluloid having holes cut in it opposite items we do not wish to have inspected after 16 hr. is laid on the card and the clerk writes "out" through each hole therein. Fewer items are marked "out" on the celluloid guide for the 32-hr. card; there are but two items marked "out" on the 48-hr. guide, and everything is inspected after 96 hr.

Methods of Inspection Described

The inspection is begun as soon as the plane taxies up to the hangar. The pilot turns the craft over to the chief night-mechanic. The second pilot has all of the troubles and defects noted on his pilot's report before he leaves the cockpit, and this affords a good start for the work to be performed. As a matter of course the mechanic runs each one of the engines himself before they are stopped and notes certain things. He checks the engine revolutions and the voltage and amperage of the generator on the center engine, the revolutions of the left engine on each magneto and the revolutions of the right engine on each magneto. Then he idles each engine and sees that the idling speed is neither too high nor too low, and that the fuel mixtures are not too rich. Before cutting off the gasoline he turns off the switch for a moment; if the engine responds to the switch and dies, that is normal, but if he turns off the switch and the engine continues to run, there is a broken switch wire or some other defect that he must locate. He notes also the oil pressure and the oil temperature, and checks up on the oil consumption of that engine between some other city and Los Angeles, thus obtaining a fair indication of the condition of the engine and how it is performing. So, with these items noted, he has made a very good start on his inspection and knows exactly what he has to do. There may be some broken accessory parts, but he knows exactly how all three engines are functioning. The engines are then cut off and, as a matter of routine, the gasoline supply is put into the tanks and the craft is wheeled into the hangar. While being towed into the hangar, the brakes are tested. Then the routine inspection begins.

Details of the Routine Inspection

Removal of the cowling exposes the engine mount. Loose bolts, cracked welds, cracked tubes or supports or broken carbureter brackets are to be looked for in the engine mount. The mechanic deals with one system at a time throughout the whole inspection. It is not feasible for him to stand on one side of the engine and inspect all he can see, because that sort of inspection makes one very liable to miss something; but, if one system at a time is traced from one end to the other, it is almost impossible to miss any defect.

The gasoline system is next on the mechanic's list. He examines the tank for leaks, the saddle or tank support as to whether it is intact, and the tank must be tight and must be "safe-tied." We have been fortunate, and have never had a leaky tank. Then he need not re-examine gasoline-tank caps that he examined when he serviced the plane.

The sump valve and the strainer in the bottom of the gasoline tank are inspected next. A small quantity of gasoline is drained into a cup and observed so as to detect the presence of water and foreign particles; afterward, about a pint is drained out to clear possible obstructions. Having thus checked the tank, the saddle and the quality of the gasoline, the mechanic traces the gasoline line from the tank to the engine, examining each hose and hose connection for worn-out hose, loose or broken hose-clamps, and sees that the lines are not chafing against some other object; if they do make contact with another part, they must be tied so that they do not rub and wear. The gasoline valves are examined and the strainer in the engine bed is cleaned. From there, the gasoline line goes to the carbureter, and the mechanic checks the hose connections as he proceeds. The carbureter has an overflow tube and, on the center engine, he must make sure that no overflow of gasoline spills down over the exhaust pipe. This completes the gasoline inspection for one engine, and the mechanic makes a similar inspection of the other two engines. Occasionally an auxiliary priming-line breaks, but that is usually about the only trouble with our fuel system.

Lubrication and Electrical Systems

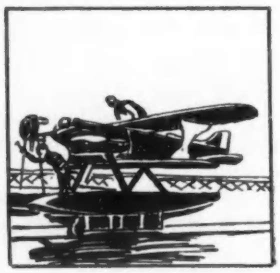
The lubrication system is inspected in much the same way as is the gasoline system. The mechanic inspects the oil tank and cap, as well as the tank saddle and the oil line for bad hose-connections and clamps. He also checks the oil-gage line and the gage. He has previously found that the gage line is functioning, and then removes and examines for foreign matter the oil screen and sump plug on the engine. This gives him an indication regarding how the inside parts are wearing; many an engine has been prevented from failure by a mechanic who dected babbitt metal in the oil screen, and this precaution is insisted upon.

The mechanic must make certain that the magnetos are bolted securely. The coupling that drives the magneto should be free. Breaker points are inspected and are reset if necessary. If, upon examining the points, he finds that the mechanism is oily, only a few seconds are needed to remove the breaker mechanism, clean it with gasoline, examine the points on the outside, replace the mechanism, and readjust the points. The bearings of the magnetos are oiled every 32 hr. according to a chart. Each magneto has three sets of wires. If the low-tension-switch wire were to ground against any part of the framework or metal work, it would cause a direct short-circuit across the points and that magneto would go out of service. Another wire leading from the magneto is a high-tension wire that is used as an aid in starting; it must be secured to the framework to prevent it from moving, and must be in good condition. Wires running to the spark-plugs must also be

gone over. Some trouble is experienced with the radio shielding on the spark-plugs by all companies throughout the Country. This is simply a metal cover on the order of the tinsel that covers the high-tension wires and occasionally a short-circuit is found at one end or the other of the spark-plug wires to the radio shielding which surrounds the wire; therefore, every 48 hr., the distributor heads are pulled out and examined. Otherwise, the ignition system is invariably good for the life of an engine between overhauls. The spark-plugs are not examined at this stage of the inspection.

While inspecting the electrical equipment, the mechanic usually checks the generator to see that the nuts holding it are tight and safe-tied, that the wires leading to and from the generator are in good condition, and that they are secured to some part of the frame or are in their proper conduits, which also must be in good condition.

The storage battery is checked by the radio man before every trip and is changed every other trip. The control box which contains the breaker mechanism is checked every 48 hr. and the points are cleaned and readjusted. Occasionally, it is necessary to readjust them oftener.



Engine-Control and Starter Inspections

Throttles must be free to move without striking or sticking, and they must be safe-tied; bell-cranks and the rods to which they are attached must be oiled and must have no lost motion. The same procedure applies to the spark lever, the altitude lever and the heater-control lever.

The temperature gage can be examined quickly; it must have no leaks where it connects with the crankcase, its connecting tube must be sound and the gage must be operating. The exhaust system requires inspection for loose or leaky sections of the pipe or joints and for broken welds. Occasionally, a strap or fitting must be re-welded. It is but rarely that an exhaust gasket needs replacement.

The electric inertia-starter is equipped with an electric motor and a small flywheel and is built in the style of a portable electric drill. A socket is provided for the starter. The starter proper on the engine is good for 300 hr. and probably for a greater time than that, the point being that we have no repair work to do on the starter between overhauls. It is a matter of making certain that the clutch operates and that the rod on which the motor that drives the flywheel fits is in good condition. The two pins that run through that rod may break, they are aircraft bolts and, in time, wear; however, since they are changed each 100 hr., little trouble is experienced. All the detailed inspection I have mentioned takes about 1 hr. of an average mechanic's time for each engine, but inspecting the valves takes about 3 hr.

Valve-Inspection and Adjustment Methods

The spark-plugs are removed so that the engine can be turned freely. The valves are then checked by "feel" with the hand, the purpose being that, if a rod is bent, or one of the ball-ends of the rocker-arm is broken, or if a tappet is crushed or a tappet roller broken, it will immediately be evident because, instead of having a clearance of several thousandths of an inch, the clearance will be say 1/4 in. After checking the valves, the push-rods are removed and that is a mean job; then the rocker-arm housings are washed out, the rocker-arms and the ball in the end of each rocker-arm are examined, and the housings are repacked with grease. The washing-out process is by means of an air spray. Occasionally, the inspector finds a broken ball immediately after washing out the housings. The housings around the push-rods are gasketed at either end to prevent the grease from spattering on the outside of the engine. Those gaskets are changed every time the housing is removed.

While that is being done, a helper washes the push-rods and push-rod housings to have them ready for the reinstallation of the rods. The rods are rapped on some part of the engine; if they are good, they will ring clearly and, if bad, they sound as if made of lead. Sometimes one is worn on the end, and this is determined by feeling it. Each rod is greased before replacing it. Then the valves are accurately checked with a feeder gage. New grease is put into the rocker-arm housings, the small half-balls and the rocker-arm pins are smeared with grease, the covers are replaced and the outside of the engine is washed.

As to spark-plug replacement, every 32 hr. both the front and the rear spark-plugs are removed and, if they have any appearance of unreliability, they are tested under pressure. A good mechanic estimates the reliability of a spark-plug by looking at it. The cowling, which has in the meantime been repaired, is then replaced, and the engine is given another trial run to make certain that it is ready to go. One knows that it is ready and, nine times out of ten, nothing needs to be done to it after the trial, but it is always given that trial run.

Expert Maintenance Mechanics Necessary

A good trouble-shooter is a necessity. It is one thing for a mechanic to be able to eliminate trouble if he has all day in which to do it, but it is another thing to eliminate trouble that develops at the last moment and still get the plane started on scheduled time. Recently, a tappet broke. It evidently was too tight, the heat expanded the rocker and broke the tappet and, before the engine was thoroughly warmed, the valve adjustment was completely out. That engine turned up to 1575 r.p.m. It was known to have turned up to 1600 r.p.m. when it came in the night before, and the lower speed of 1575 r.p.m. was the indication that something was wrong with it. One class of maintenance man probably would not have found the trouble until long after the scheduled departure-time, but the expert trouble-shooter found the trouble quickly and the plane departed on time. That is what I call good trouble-shooting; but maintenance such as that is costly.

Planning Maintenance Is Essential

Careful planning will accomplish much toward reducing maintenance costs. Supplying the men with suitable tools and adequate shop equipment is a large factor, and the balancing of classes of labor is also important; that is, a mechanic should do mechanic's work and a helper should do helper's work. To allow a mechanic to do helper's work is poor business as it increases costs.

After considering several modern airplane-designs, I think that the greatest reduction of maintenance cost can be made by redesigning the engine installation. For example, one type of cowling is pinned on with safety pins, and it takes 45 min. to pull the cowling off of three engines. That is wrong and it can be improved. In another instance the small drain-plug in the bottom of an oil tank could be replaced by a large cock that would drain the tank quickly, and this is important because it has to be done every other trip. Gasoline strainers usually are inaccessible. Vital fittings are often well covered up by what we call "dumdum," which may keep the wind from blowing into the cockpit, but it has to be removed once in a while to see that the fitting is in good condition. All types of vital fittings should be accessible on all types of airplane. Any fitting of importance should be out in the open where it is being watched every time the cowling is off. That is not always possible; but a long step could be taken in that direction, and that is true of almost all airplanes. Special maintenance tools are just as important as shop equipment.

The cooperation of the men who do the maintenance work gives a more brilliant performance, but the lack of it causes trouble. We worry too much about what we have to do today and not enough about where we and our work will be 10 to 20 years from now. It is all in the point of view. If one has a dozen or more mechanics working for him who are asking themselves the question, Where will I be 10 years from now? the cooperation of the men will be secured from their selfish viewpoint, as well as from other influences. Among these are that the automotive industry is furnishing the men with their bread and butter, has been doing so for years, and that they expect it to continue to do so. They realize that they are spending the best years of their lives in the industry, expect to spend their remaining years with the industry, and that they owe the best they have to that work. Another incentive is that each man has a chance to help the game along, knows that he will get out of it just what he puts into it, and also that there are unlimited opportunities for men who are working around things that are wrong or using methods that can be improved upon. Therein lies opportunity.

One opportunity that each of our men has is to reduce the cost of maintenance by eliminating wasted movements. On a large airplane, a man can wear himself out while getting ready to go to work; but if he has carefully planned his work, he can run through with the items mentioned within a reasonable time, and it is our responsibility to see that he does not spend 10 hr. doing an 8-hr. job.

Trouble and Complaint Records Essential

Detailed trouble and complaint records make possible a periodic study of past failures and past expenses. The records can be applied to magnetos, carbureters and all the other parts.

The installation is at fault in most cases. For example, the only thing that could materially reduce maintenance trouble and cost on our particular engine is a different sort of a lubrication system for the valve mechanism; a system that would allow us to check our valves in 45 min. instead of the 3-hr. period that it now takes. By better engineering and planning, I think we will be able to check the valves on our engines in 45 min. The matter can all be summed up in the word "accessibility."

Regarding accessories, we are using spark-plugs with which we get along very well, but they are not just what we need. The reason is that some certain kind of plug may operate over the desert and do well; but, after landing at the next station and idling while waiting for passengers, the plug is found to have become fouled. It is too cool to burn all of the oil that accumulates in 5 to 10 min. But a plug that is hot enough to burn the oil is likely to be a short-lived plug. It will operate well at high speed but will burn away rapidly.

Battery Accessibility and Maintenance

It is unfortunate that an aircraft battery usually is located so that it is almost impossible to gain access to it without tearing the ship apart. An accessible battery is a necessity. I believe a battery "jelly" is on the market, but I understand that this battery can be checked only by a voltmeter, and that one cannot tell just how much of a charge the battery contains; so, until we can find a way of testing that jelly, we will continue to use the acid solution. However, if the jelly is as good as the claims for it indicate, our battery trouble is about over.

It certainly would be advantageous to change engines in 30 min. instead of a day and a half. There is no reason why the engine mount, the oil tank, the propeller and, if necessary, the cowling could not be installed with the engine as a unit and be changed after pulling out a few bolts and have it over with. This will be done eventually, but it is time to do it now. If we could do that now, in some cases we could turn loose an $80,000 airplane for service while we tied up a $10,000 engine for repair. If a gear should break, within 30 min. we could replace the powerplant and send the plane out.

In conclusion, it is my opinion that none of the work mentioned should be slighted in the least, but that each transport organization should employ a man who would study methods of eliminating waste time and material and have a vote on proposed changes in new planes. With that sort of set-up, an organization can maintain the standard of mechanical performance at a very much more reasonable cost.

THE DISCUSSION

LIEUT.-COM. L. B. RICHARDSON[2]:—In San Diego, we are overhauling the same kinds of engines mentioned by Mr. Cain. The Pratt & Whitney Co. engines cause trouble due to wear of the aluminum-alloy parts that are in contact with steel. In the Wasp, we find that the crankcase wears around the thrust bearing and allows the crankshaft to whip and to get as much as 0.030 to 0.040 in. out of line. I believe that no thrust bearing of steel of the size used there should be run in the aluminum-alloy case. It has been corrected by the

(Concluded on p. 586)

[2] Construction Corps, United States Navy, Naval Air Station, San Diego, Calif.

Light-Weight Diesel-Engines

By O. D. Treiber[1]

Annual Meeting Paper — *Illustrated with* Photographs

MARINE and stationary units were the only Diesel engines that could be sold until within a comparatively few years. Slow speed was required for marine engines, for reasons of propeller efficiency, and prejudice required stationary engines also to be heavy.

Naval requirements reduced the weight, but only in engines that were too expensive for commercial use. Light-weight engines must run at high speeds, utilize high-strength materials at high stresses, and develop high mean effective pressure.

With equal mean effective pressures, Diesel engines can be made only about 15 per cent heavier than corresponding gasoline engines for motorcoach and motor-truck service. The paper closes with a description of a number of the mechanical details of the Treiber engines.

In the discussion, the author says that hard piston-rings prevent cyilnder wear; and that Diesel engines idle reliably, because burning does not depend upon an accurately metered mixture. Fuels and their impurities are considered, and questions as to mean effective pressure are answered. Data is given on spray velocities under various conditions.

DIESEL engines have long been important prime movers, but only lately has any interest been shown in the light-weight Diesel. The development of this art has been limited almost entirely to the demand, because of the great cost and time required for development. Marine and stationary units were the only salable Diesel engines for about 20 years, and the purchasers of these types demanded heavy, slow-speed machines. Particularly was this true for marine service, in which slow speed, in some cases as low as 100 r.p.m., was required for high propeller efficiency. Weight and revolutions per minute had no significance in stationary service, except that purchasers were led to demand a heavy engine by the arguments that weight and slow speed meant a greater degree of strength and strength meant long life and low cost of upkeep.

The weight of some of the earlier proved types of Diesel engines was as high as 500 lb. per hp., although others weighed as little as 175 lb. per hp. Piston speeds were low, from 650 to 800 ft. per min., and many specifications drawn by important purchasers limited the piston speed to 700 or 800 ft. per min.

Mean effective pressures of the earlier successful engines using air injection averaged about 75 lb. per sq. in. Attempts to increase the mean pressure for long tests usually resulted in cracked pistons, cracked cylinder-heads and even cracked cylinder-liners. The combustion was usually poor at higher mean pressures. This caused piston-rings to stick and resulted in further trouble, often disastrous. Other things militated against the development of the light-weight Diesel-engine for many years; among them the keen competition and demand for low-cost engines, which forced the engineer to use the cheapest materials obtainable and to utilize existing patterns and jigs.

Shipping-Board Conversion Was Large Order

About 1923, the United States Shipping Board was authorized to spend $25,000,000 in converting Shipping-Board steamers into motorships. While no complete figures are available for comparison, this amount was probably greater than had been spent in purchasing all the Diesel engines that had been bought in America for commercial service up to that time. This was expected to give a great impetus to the development of Diesel engines, and to some extent it did. However, the specifications that were drawn required both main and auxiliary engines of 110 to 120 r.p.m. These engines weighed from 300 to 400 lb. per hp. A number of sizes of engine weighing 100 to 150 lb. per hp. were put on the market from 1920 to 1924, and they encountered great selling resistance because of their light weight.

Naval requirements for light-weight engines brought the weight down to about 60 lb. per hp.; but successful engines of this weight were too expensive for commercial use, and there has been no Naval demand at all since the Armistice.

The possibility of Diesel-powered locomotives has made its contribution to the development of lighter Diesels; but the demand has been more of an interest than a real demand, and very little money has been made available for development in this field.

And so the Diesel engine existed for about 30 years, with little development toward the light-weight engine.

After the war, the need of economical engines for motorcoach and motor-truck service in Europe resulted in the development of some Diesel engines for this service. Many types of them are in service today and are more or less satisfactory. Among these are the Junkers two-cycle opposed-piston type, the Benz, the M.A.N., the Renault, the Morton and the Deutz. Reasonably light weight and low first cost are demanded of engines for this service.

Means for Reducing Weight

To reduce the weight of a Diesel engine we must, first, increase the rotative speed; second, use higher-strength materials and stress them more highly; and, third, increase the mean effective pressure.

The limitations of high rotative speed are very similar to those of a gasoline engine, excepting possibly the limits imposed by the lag of ignition, and this lag is greatly varied according to a number of different conditions such as temperature of fuel and compressed air and velocity and fineness of spray. Reduction of weight

[1] M.S.A.E.—President, chief engineer, Treiber Diesel Engine Corp., Camden, N. J.

by the advanced use of metals is also a problem somewhat similar to gasoline-engine problems; but increasing the mean effective pressure is distinctly a Diesel-engine problem, with a wide range of results under different conditions.

The old pros and cons of two-cycle versus four-cycle type assume greater significance. Both types have advantages and will be developed further, but in both types are found the difficult problems of securing high mean effective pressure and good thermal efficiency and of keeping the maximum pressure within reasonable limits.

Up to 1920, the Diesel engine was built almost universally with high-pressure blast-air for injecting the fuel. This method can be considered obsolete today for light-weight Diesel-engines. Solid injection is now used successfully and will, in my opinion, remain as the standard method. However, a great number of solid-injection methods exist, and they can be classed in two principal groups: first, the constant-pressure system and, second, the individual-pump system.

The constant-pressure system delivers a fine spray through a properly constructed spray-nozzle. The individual-pump system may be used with either a fine spray or a coarse spray, depending on the type of nozzle.

Plain and Auxiliary Combustion-Chambers

Combustion-chambers have been shaped in many ways but all can be divided into two distinct classes, as plain or auxiliary.

Each type has advantages and disadvantages, but no method is perfect or greatly superior to all others.

The auxiliary combustion-chamber has advantages in that it permits greater turbulence, thus allowing a coarser spray; but it has greater radiating surface and prevents a complete union of the hydrocarbons with the oxygen early enough in the stroke for high expansion-ratio and the attainment of high mean effective pressures, and the thermal efficiency is not as high as is required for light-weight engines. The plain combustion-chamber has the minimum surface, and radiation is consequently at the minimum. With suitable turbulence and control of the fuel spray, the chemical union of oxygen and hydrocarbons can be controlled, to keep the maximum pressure within reasonable limits, and

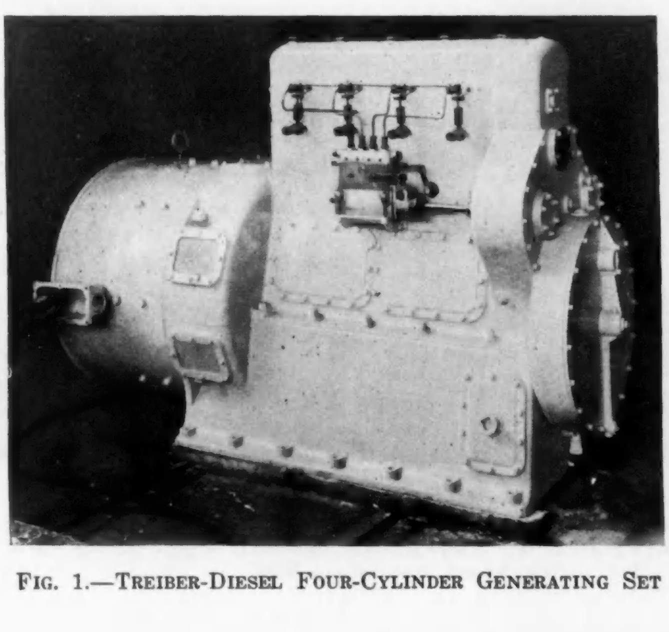


Fig. 1.—Treiber-Diesel Four-Cylinder Generating Set

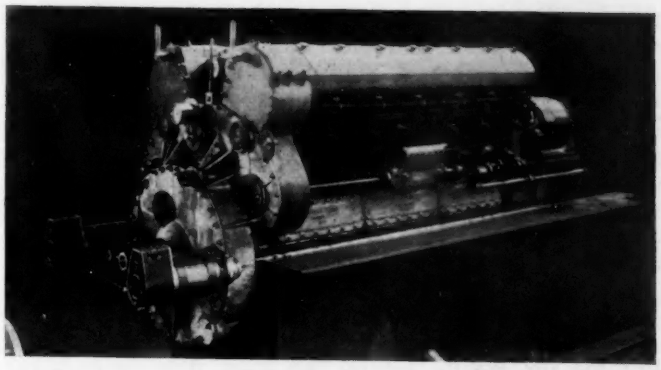


Fig. 3—Twelve-Cylinder 300-Hp. Treiber-Diesel Engine

continued to completion early enough and fast enough to give reasonably constant pressure, resulting in high mean effective pressure.

However, the control of the spray and the turbulence is not so easy in small cylinders as in large ones. A coarse spray will travel from 200 to 400 ft. per sec., and a fine spray from 600 to 1100 ft. per sec. Traveling at this velocity, the liquid fuel is liable to come in contact with the walls of the combustion-chamber before it is gasified and its temperature raised sufficiently to form a chemical union with oxygen, unless it has a considerable distance to travel. Not much distance is available in small cylinders, and the spray will decompose and build up a sticky mass of carbon if it comes into contact with the walls of the chamber, the exhaust will be smoky, and the engine will have poor economy.

Pressures and Thermal Efficiency

Consideration of the limits of mean effective pressure and thermal efficiency will give us a goal to work toward. Exceptional indicator-cards, taken on slow-speed engines, indicate that high mean effective pressure has been accomplished. I have built large slow-speed engines developing 100 lb. per sq. in. brake mean effective pressure from 0.40 lb. of fuel per brake horsepower-hour, and other engines at 85 lb. per sq. in. brake mean effective pressure with fuel consumption of 0.37 lb. per b.-hp-hr., and maximum pressures not over 700 lb. per sq. in. It must be remembered that thermal efficiency and mean effective pressure go up as maximum pressure goes up. If the pressure is increased to 1200 or 1500 lb., the economy will be improved, but it will be at the expense of more highly stressed or heavier parts. To compare Diesel-engine performance, we must know three things: fuel consumption, mean effective pressure and maximum pressure.

A number of engines embodying electric ignition and a special type of gas generator and carbureter have been built to utilize heavy fuel-oil with some degree of success. A type of generator is now perfected which will gasify fuel-oil without the usual carbon deposits; and the resulting gas, when carbureted, gives excellent economy at predetermined loads and speeds but has very little flexibility and requires gasoline for starting. This fact, coupled with the requirements of electrical ignition and a carbureter, complicates the engine and adds to its cost. Furthermore, the thermal efficiency is not as high as that of a self-ignition injection engine.

Weights of aircraft gasoline engines vary between slightly less than 2 to about 4 lb. per hp. The Diesel types of engine for this service which have been built

and flown are radial four-cycle, opposed-piston two-cycle, and in-line four-cycle. Other types, which are in process of development, may reveal some strikingly new features. Diesel engines weighing less than 2 lb. per hp. will be available in the not very distant future, with fuel consumption of about 0.37 lb. per b.hp-hr. Engines of these types are not suitable for motorcoach, motor-truck or other commercial service, either stationary or mobile, and their cost is prohibitive for anything but air service.

Foundry Conditions Limit Lightness

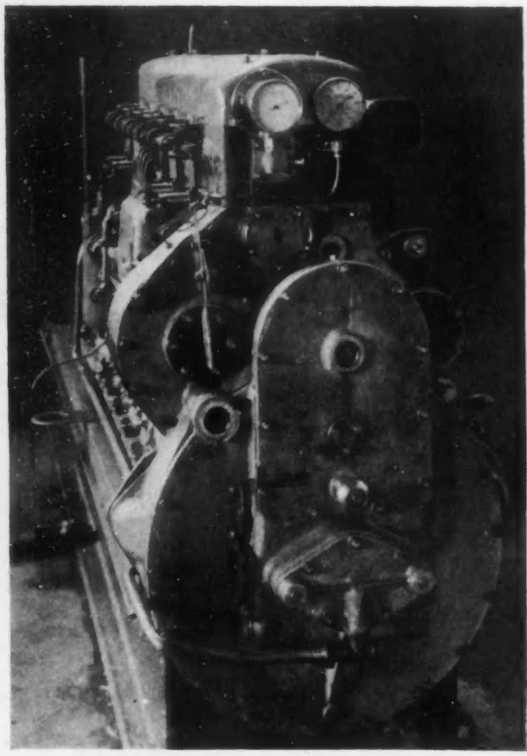
Coming back to types of light-weight Diesel-engines suitable for mobile service, we have first to consider that engines must be produced cheaply; at something near the cost of gasoline engines. This requirement introduces a weight-limiting factor that is dependent upon foundry limitations. Truck and motorcoach gasoline-engines weigh from 10 to 18 lb. per hp. It is possible but not economical to build them lighter. A Diesel engine for the same service should weigh not much more than the gasoline engine. A differential of about 15 per cent is to be expected, because of the higher pressures used; it is possible to restrict the increase in weight to this, provided mean effective pressures are equal.

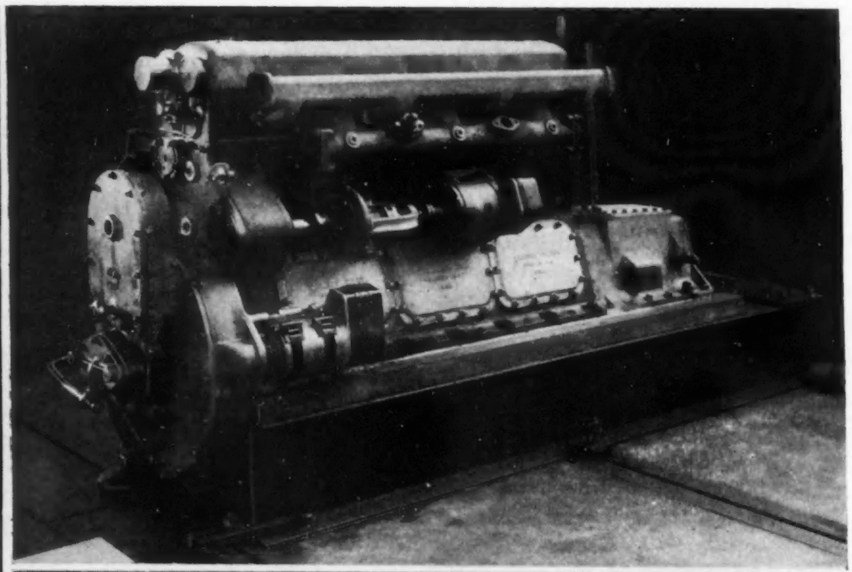
We have developed a line of engines that weigh 15 to 20 lb. per hp. They are rated at speeds of 1000 to 1200 r.p.m., although very satisfactory runs have been made on the test stand at 1500 and 1800 r.p.m. A four-cylinder engine of the 5 x 7-in. size is shown in the form of a generator set in Fig. 1, and Fig. 2 includes three views of a six-cylinder 100-hp. marine engine having the same cylinder dimensions. The 6 x 8-in. size, in the form of a 300-hp. twelve-cylinder V-type marine engine, is shown in Fig. 3.

The heads are separate from the cylinders and are fitted with one inlet and one exhaust valve for each cylinder. These valves are pocketed into the cylinder liner, to make possible large ports, ample water circulation and suitable location for the spray nozzle.

The camshaft is mounted in the cylinder-head. A formica gear on the camshaft is driven by a pinion which is mounted eccentrically on the cylinder fame, together with a sprocket, and driven from the crankshaft by a roller chain. The chain also drives the pump shafts and has idlers for adjusting its tension.

Starting is accomplished by an electric motor, and a compression-relief is provided to reduce the starting torque. Force-feed lubrication is used throughout. Entering at the forward end, oil passes through the entire length of the hollow crankshaft. Openings are pro-





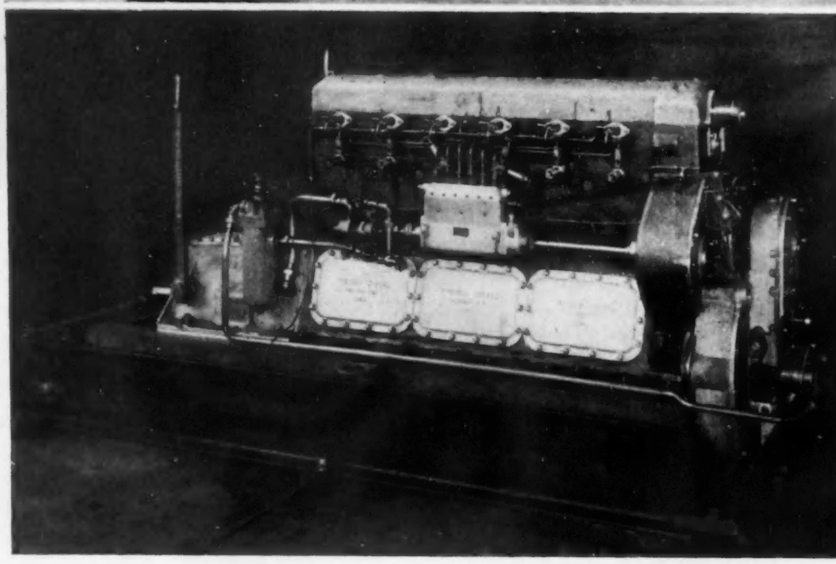


Fig. 2—Six-Cylinder 100-Hp. Treiber-Diesel Marine Engine

The View at the Left Shows the Forward End of the Engine, the Lower View at the Right Shows the Fuel-Pump and Injector, and Other Engine Accessories Are Seen in the Upper Right View

vided for all bearings, and a gage registers the pressure on the furthermost bearing. The oil also passes into the reverse gears at the after end of the crankshaft. A branch from the main feed-line leads to the hollow rocker-arm shaft and lubricates the rockers, cams and camshaft bearings.

THE DISCUSSION

L. F. BURGER[2]:—Does the upper end of the cylinder-liner wear faster than the lower end, on account of the piston-rings and the higher pressure during the first part of the stroke?

O. D. TREIBER:—The upper end always wears more, because the cylinder pressure gets under the rings and expands them against the cylinder-wall. The idea is erroneous that greater ring pressure is needed to hold higher compression; the pressure in the cylinder takes care of that.

In the case of one engine, which we did not build, the wear at the top of the cylinder was 0.001 in. each 24 hr. Two cylinders of another engine, which had run 4500 hr., were worn about 0.001 in. at the top and not at all at the bottom. The wear is least with good lubrication, hard cylinders and hard piston-rings. If the cylinder and rings are soft, any sediment in the fuel will form a grinding compound and make lapping tools of the rings.

MR. BURGER:—In one engine that I saw, the top ring wore the cylinder-sleeve 0.008-in. oversize for about ½ in. down from the top of the piston travel in about 300 hr. Below that point, the cylinder sleeve was not worn. Does changing the cylinder pressure affect the wear materially?

MR. TREIBER:—What you describe must have been caused by some peculiar condition. Probably the top ring was soft and acted as a lap. Changing the cylinder pressure makes no perceptible difference in cylinder wear.

O. D. TREIBER

R. TOM SAWYER[3]:—It seems to me that a Diesel engine must have a large number of cylinders in order to approach the slow idling speed of a gasoline engine. What is the idling speed of a twelve-cylinder Diesel engine?

Diesel Engines Reliable in Idling

MR. TREIBER:—The Diesel engine is inherently better than the gasoline engine for idling, because all the oil will burn if it has sufficient oxygen and the temperature is high enough. The actual slow speed of an engine depends upon the kinetic energy of the rotating parts and the variation in torque. We have built six-cylinder 12½ x 18-in. engines with 54-in. 2-ton flywheels which ran under load at 45 r.p.m. We have run a 5 x 7-in. six-cylinder engine, having a flywheel such as would be used for automobile work, at 150 r.p.m., and the 6 x 8-in., 300 hp. twelve-cylinder engine shown in Fig. 3 ran at 100 r.p.m. on test. The Diesel engine is inherently more flexible than the gasoline engine, for it will accelerate more quickly.

MR. SAWYER:—I have driven oil-engined trucks of several makes, none of which could be run slower than 8 m.p.h. in high gear. If the engines had more than four or six cylinders and had excellent torque at speeds from 100 r.p.m. upward, that would be very desirable, but it seems to be difficult to get oil engines to idle at very low speeds.

P. H. SCHWEITZER

P. H. SCHWEITZER[4]:—According to my experience, idling at low speeds depends upon the injection system. If atomizing pressure is maintained at low speeds, the engine will idle nicely. Reducing the speed by one-half cuts the injection pressure to one-fourth in engines of many types. If the injection pressure is not much more than is needed at ordinary running speed, it would be entirely insufficient at a low idling speed.

R. W. A. BREWER[5]:—Why is it that the specific output of Diesel engines, with their high compression, usually is less than that of gasoline engines with their lower compression-ratio? I am thinking particularly of aviation work.

MR. TREIBER:—We may reasonably expect Diesel engines of 4 and 5-in. bore to run at speeds comparable with those of gasoline engines and fuel consumptions of about 0.45 lb. per hp-hr. This is less than one-half the fuel consumption ordinarily found in gasoline engines on the road. For aviation engines, it is reasonable to expect that we will have engines delivering 100 lb. per sq in. in m.e.p. at a fuel expenditure of 0.40 lb. per b.hp.

MR. BREWER:—Is there no reasonable possibility of securing something like 150 lb. m.e.p. with moderate fuel consumption?

Developing High Mean Effective Pressure

MR. TREIBER:—One of our large engines has developed an indicated mean effective pressure of 160 lb. per sq. in., with a fuel consumption of 0.425 lb. We cannot expect to equal that performance regularly, even under ideal test conditions. A mean effective pressure of 120 lb. with fuel consumption of 0.4 lb. can be attained if the maximum pressure is made high by burning at constant volume, but this practice involves very high stresses. If the maximum pressure is 1500 lb. per sq. in., the fuel consumption can be materially below 0.40 lb., but it seems more practicable to use a lower maximum pressure at the expense of slightly higher fuel consumption.

[2] M.S.A.E.—Chief engineer, International Harvester Co., Chicago

[3] Jun.S.A.E.—Automotive equipment specialist, General Electric Co., Erie, Pa.

[4] M.S.A.E.—Associate professor of engineering research, Pennsylvania State College, State College, Pa.

[5] M.S.A.E.—Consulting engineer, Aircraft Engine & Accessory Development Corp., Passaic, N. J.

MR. BREWER:—Has Mr. Treiber worked on two-cycle engines, and does he think they are promising for high-speed development?

MR. TREIBER:—I think the possibilities of two-cycle Diesel engines are very great; the chief obstacle is the difficulty in exhausting and recharging the cylinder in the short time allowed.

HAROLD CAMINEZ[6]:—Is it not possible to obtain high mean effective pressure in a Diesel engine by providing 200 per cent volumetric efficiency with supercharging? The expansion ratio would still be the same and the mean effective pressure would be higher.

A. J. POOLE

MR. TREIBER:—If an engine is to be supercharged to 200 per cent of its piston displacement, provision must be made for the same supercharging in starting. If that can be arranged for, the output certainly will be greater, but the fuel consumption will be more than proportionately greater.

MR. BURGER:—Before Diesel engines are an unqualified success, the fuel situation must be considered. We must have clean fuel, and my observation is that the available fuel contains so much foreign matter that it will destroy the pumps, spray nozzles and cylinders in a short time. What are the best methods available for filtering or purifying the fuel?

MR. TREIBER:—If the fuel is dirty, it is very necessary to centrifuge it or pass it through some sort of a separator to eliminate the foreign matter. You are quite right in saying that we must have clean fuel; if you have dirt in the fuel, you are all done before you start.

We use strainers of various kinds; we always pass the fuel through a 250-mesh screen before it goes into the pump and then through a tube strainer on the way to the nozzle. That is about 99 per cent sure to remove every impurity that might cause trouble.

Fuels for Diesel Engines

C. M. LARSON[7]:—To an oil man, furnace oil seems like the logical fuel for a Diesel engine. This is now distributed in tank-wagon lots, and is available for automotive purposes.

CHAIRMAN A. J. POOLE[8]:—I believe that an oil of much lower grade than furnace oil, and consequently cheaper, can be used.

MR. LARSON:—An oil having too high a pouring-point will not flow from the tank to the engine during cold weather. Furnace oils will flow down to zero and lower.

CHAIRMAN POOLE:—Have you had any trouble in feeding 24-deg.-Baumé fuel?

MR. TREIBER:—We have used all kinds of oil in the various engines we have built. When we learned to burn West Coast oil, we thought that was the hardest to burn; but we had to learn our lessons all over again when we began with paraffin-base and other Eastern oils. We used oils ranging from 40-deg. Baumé downward. In one case we obtained some 8-deg.-Baumé oil in Cleveland. The day was hot, and the oil flowed like 24-deg. oil and was entirely satisfactory to the crew of that boat during a run of three or four hours.

About seven years ago, we ran a test for the Government in which the specifications called for a fuel containing 5 per cent of asphalt. I believe the Baumé reading was 12 deg., and the oil would not run out of the barrel; we were obliged to use an air pressure of 50 lb. per sq. in. to transfer the oil. This fuel had to be heated before we could pass it through the pipe, and we usually were obliged to start the engine with a better grade of fuel. However, the engine operated quite all right with this fuel after it was started.

We have not tried the heavier oils in small engines having individual pumps and spray nozzles. In my opinion, nothing below 24 deg. on the Baumé scale is worth considering for engines in which the oil must be passed through small ports into the pumps.

A. L. BEALL[9]:—The chief trouble with using the heavier oils seems to be that they require a little more care in operation. Most of the heavier oils require centrifuging, and many of them need heating. I believe that the point raised by Mr. Larson is largely one of nomenclature; furnace oil approaches the gas-oil cut, which also is very generally sold as Diesel fuel-oil.

C. L. CUMMINS[10]:—I have just completed a run of 2500 miles in an automobile equipped with one of our Diesel engines. We filled up with oil only four times during this trip. When we started on this trip, the temperature was about 15 or 20 deg. fahr. We started with a mixture of 30-deg. and 20-deg. oil, blended to give a Baumé reading of about 24. This gave us the best results of any fuel that we used on the trip. The second filling was with furnace oil, about 28 to 32 deg., which we secured in Harrisburg. The third filling was about the same, obtained near Baltimore; and the last filling was in Toledo, with 32-deg. furnace-oil. This last was the least satisfactory, because it had not enough lubricating quality to be suitable for the fuel-injection apparatus until we put lubricating oil in the tank.

A. M. ROTHROCK

Impurities Hard to Remove from Fuel

MR. BURGER:—We know that heavy fuel-oils cannot be used in high-speed Diesel engines, and an attempt is being made to draw up specifications for two grades of fuel. The problem in which I am most interested is that of getting the dirt out of the oil. I have passed oil through screens of 250 mesh and 400 mesh and still find foreign matter. A felt filter will become clogged in two or three hours with matter that will pass through a 400-mesh screen. If some of this is gathered on filter paper and rubbed on glass, it will roughen the glass. Material like this will ruin the pumps and the cylinders in a short time.

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[6] M.S.A.E.—Engineer in charge, aircraft engine division, Cadillac Motor Car Co., Detroit.

[7] M.S.A.E.—Supervising engineer, Sinclair Refining Co., New York City.

[8] M.S.A.E.—Manager, manufacturers' sales department, Robert Bosch Magneto Co., Long Island City, N. Y.

[9] M.S.A.E.—Engineer, Vacuum Oil Co., New York City.

[10] A.S.A.E.—President, general manager, Cummins Engine Co., Columbus, Ind

MR. SCHWEITZER:—I suggest using a filter, like the Zenith or the Cuno, that does not become clogged yet takes out nearly all of the dirt. These filters consist of metal strips between which the fuel must pass; and they can be adjusted so that no particle can pass that is larger than say 0.002 in. Another possibility is using a fuel injector which is less sensitive to dirt and less subject to clogging.

HARTE COOKE[11]:—We have had Diesel engines in operation for about 15 years and have never encountered serious difficulty from dirt. For several years we have used lapped plungers, fitting very tightly in bushings, in the fuel-pump. We have never found any trouble with them from dirt after cleaning the fuel by ordinary methods.

A VISITOR:—Some time ago we had a request from a railroad company, that was using Diesel engines with 8000-lb. per sq. in. injection pressure, for a filter to stop erosion trouble in the nozzle. I thought that the trouble was due to the high velocity, but we found that a large filter would remove several pounds of dirt at every cleaning, which was done at the end of periods of two weeks. With such a filter in use, no more trouble was found from erosion.

Does Mr. Treiber find that any particular kind of piston-ring prevents excessive wear of the upper ends of cylinder liners?

What is the speed of the inertia starter he has described and what is its rotating weight in relation to the weight of the rotating parts of the engine?

Hard Piston-Rings Cause Less Wear

MR. TREIBER:—It is our belief that the hardest rings cause the least wear. Sooner or later I believe we will use steel rings entirely. I have come to the point where I am ready to try chromium-steel rings in place of cast-iron. Recently we overhauled an engine that was equipped with very hard steel rings and had been in service about four years. The wear on the liners of this engine was imperceptible; they were in perfect condition.

Our experience with rings has not been consistent, but we use double-seal rings to a large extent. We have had fairly satisfactory results with plain rings in ground liners and reamed liners. The plain rings would not hold well with honed liners, while double-seal rings hold perfectly. We try to use at least two double-seal rings with lapped liners. We find less trouble from leakage of gas into the crankcase in high-speed engines than in low-speed engines.

The inertia starter of a 5 x 7-in. engine has a flywheel weighing about 90 lb., and it is spun at about 1500 r.p.m.

A VISITOR:—Does Mr. Treiber find it better to use a large number of rings to prevent blow-by, or to make a sacrifice in this respect to save wall friction?

MR. TREIBER:—I believe it is necessary to prevent blow-by; otherwise, the lubricating oil will be carbonized. One double-seal ring will stop blow-by. Our practice is to use one deep, plain ring at the top to transfer as much heat as possible to the walls. Below that we use two double-seal rings and one oil-drain ring.

WILEY BUTLER[12]:—If oil engines were run entirely on distillate fuels, the sediment, of which Mr. Burger complains, would be reduced to the minimum. The viscosities of these fuels are so low that sediment will not be carried in suspension and thus find its way into the pumps and injection nozzles; furthermore, the use of such fuel would prevent the formation of carbon and pitch in the cylinders and combustion-chambers.

I recommend that fuel having a viscosity between 40 and 60 on the Saybolt universal scale be used. A viscosity of 40 is sufficient to prevent excessive wear on the plunger, and 60 is not high enough to carry any considerable amount of the material in suspension. If distillate fuels having end-points of 700 to 725 deg. fahr. are specified, most of the trouble will be eliminated. Heavier fuels are found to cause trouble also because of slower burning.

A VISITOR:—The filters that were successful in preventing erosion of the nozzles at high pressure had a porosity that was sufficiently fine to reduce the bacteria count in water.

J. E. WILD[13]:—That bears out our experience in filters. I observed a notable improvement in the metal filters that were exhibited at the recent electric railway show in Atlantic City, but I doubt whether any metal filter is fine enough to make oil sufficiently clean for injection.

Data Given on Spray Velocity

ADDISON M. ROTHROCK[14]:—Mr. Treiber stated that a coarse spray will travel from 200 to 400 ft. per sec., and a fine spray from 600 to 1100 ft. per sec. The figures for the fine spray, while applicable to sprays in air at a density of one atmosphere, are probably too high for air densities in the neighborhood of 15 atmospheres, the condition met with in the combustion-chamber of a Diesel engine.

We have measured spray-tip velocities by taking tangents to the time-penetration curve of the spray photographs obtained with the N.A.C.A. spray-photography equipment. For an air density of 20 atmospheres and an injection orifice 0.015 in. in diameter, the spray-tip velocity after 0.0002 sec. varied from 130 ft. per sec. for an injection pressure of 2000 lb. per sq. in. to 440 ft. per sec. for an injection pressure of 8000 lb. per sq. in. Harold F. Miller and Edward G. Beardsley have shown that, at the end of 0.0005 sec., the tip velocity for the 2000-lb. per sq. in. pressure was 110 ft. per sec. and for the 8000-lb. per sq. in. was 230 ft. per sec.[15]. It has been shown by Dr. R. Kuehn[16], Ludwig Hausfelder,[17], and Dr. F. Sass[18] that, for any given nozzle, the size of the fuel drops decreases as the injection pressure increases. Consequently we can conclude that, for equal-diameter orifices, both the penetration and the fineness of the spray increase with increasing injection pressure. This is in general agreement with Mr. Treiber's statement.

However, if we keep the injection pressure constant

[11] M.S.A.E.—Engineer, McIntosh & Seymour Corp., Auburn, N. Y.

[12] Standard Oil Co. of New Jersey, Elizabeth, N. J.

[13] M.S.A.E.—Vice-president, Robert Bosch Magneto Co., Long Island City, N. Y.

[14] Assistant physicist, National Advisory Committee for Aeronautics, Langley Field, Va.

[15] National Advisory Committee for Aeronautics Technical Report No. 222, by Harold F. Miller and Edward G. Beardsley, 1927.

[16] National Advisory Committee for Aeronautics Technical Memorandum No. 330, by Dr. R. Kuehn, September, 1925.

[17] National Advisory Committee for Aeronautics Technical Memorandum No. 403, by Ludwig Hausfelder, March, 1927.

[18] Kompressorlose Dieselmaschinen, by Dr. F. Sass, pp. 41 to 49; published by Julius Springer, Berlin, 1929.

and vary the discharge-orifice diameter, the opposite is true. Dr. Sass has shown that, for equal injection-pressures, the atomization becomes finer and more uniform as the orifice diameter is decreased. Spray-photography records obtained at the Langley Memorial Aeronautical Laboratory have shown that, for an injection pressure of 8000 lb. per sq. in. and an air density of 17 atmospheres, the tip velocity after 0.0002 sec. was 390 ft. per sec. for a 0.014-in. orifice and 430 ft. per sec. for a 0.040-in. orifice. The spray-tip velocity after 0.001 sec. had decreased to 220 ft. per sec. for the 0.014-in. orifice, but had not changed sensibly for the 0.040-in. orifice. In this case, the coarse spray from the large orifice penetrated farther than the fine spray from the small orifice, although the injection pressure remained the same.

The following conclusions can be drawn from these data:

(1) For equal orifice diameters, both the penetration and the fineness of the spray increase with an increase in injection pressure.

(2) For equal injection pressures, the penetration increases but the fineness of the spray decreases with an increase in orifice diameter.

Aircraft-Engine Inspection

(*Concluded from p.* 579)

Pratt & Whitney Co. by putting in a liner that can be replaced. We also have had trouble around the impeller drive that goes through the aluminum-alloy blower-section of the case. Many engines collect oil in the bottom cylinders.

There should be no movement between the bushing and the case; but, apparently, there is a breathing between the two with the changes of pressure in the cylinders, so that looseness develops in the aluminum-alloy case. For that reason we have to ream out the case, manufacture a duralumin sleeve, make a driving fit in the case and ream the sleeve again to get the brass bushing around the shaft to fit.

Piston failures have occurred in several cases, and are being remedied by putting the master rod in No. 6 cylinder, substituting a piston of a lighter alloy, and putting in bronze wristpin plugs to make up for the decreased weight of the piston. Various things like that come up with military aircraft that I suppose do not occur in commercial airplanes.

One of our greatest troubles is dirt. We find pistons worn as much as 0.025 and 0.030 in. after 250 to 300 hr. of service, and piston-rings worn so badly that they break in two and double up. Another thing we notice particularly is wear of the cylinder-walls. I think the material being put in the cylinder-walls is not hard enough; this is a matter that all manufacturers of engines for the vicinity of California, where there is so much dust, might well take into account.

We find numerous cracks in aluminum-alloy parts. I believe that forgings should be developed as rapidly as possible as substitutes for castings for all parts that have to carry stresses.

CHARLES S. CAIN:—I probably did not make my point clear that the troubles we have with the engines are not during the time that the engine is installed and functioning, but during overhauls we find some of the same troubles that Commander Richardson has just mentioned. Another trouble was that of cylinder-heads being found loose on an inspection for overhaul. We have had some trouble due to oil leaking past the blower section and I understand that some companies are prepared to re-bush the plate. In one case an engine jetted up grease on the engine-test stand, and we remodeled the plate by opening two holes in the small channel that drops down from the slinger, and removed the plate because it threw too much oil. The engine was literally reclaimed in that way; it was found that the blower section was full of oil when that engine was dismantled. After a test, there was only a film of oil over the surface, and we had adjusted it to the right clearance.

CHAIRMAN ETHELBERT FAVARY[3]:—A new aluminum-alloy which the Aluminum Co. of America developed some years ago was so hard that it was practically non-machinable; but, since the advent of tungsten-carbide steel, it can now be machined. It has a very low coefficient of expansion, and I am looking forward to the advent of a new development in pistons made of this new aluminum-alloy.

[3] M.S.A.E.—Consulting engineer, Moreland Motor Truck Co., Los Angeles, Calif.

Combustion-Chambers, Injection Pumps and Spray Valves of Solid-Injection Oil-Engines[1]

By J. E. Wild[2]

Annual Meeting Paper — *Illustrated with* Drawings and Charts

HANDLING the fuel of solid-injection Diesel engines, from the time it leaves the tank until it has been burned in the combustion-chamber, is covered fully in this paper, which is divided into three parts. The first part deals with the form of the combustion-chamber as it is related to the problem of securing combustion of all the fuel injected, with the least excess of air, and includes a study of the atomization of the fuel.

Injection valves, both open and closed, are treated in the second part, in which formulas and other information are given to help in selecting nozzles and proportioning apertures according to the speed and power requirements of the particular engine.

Injection pumps are described in the third part, with particular attention to methods of securing the desired timing, quantity of fuel and characteristics of injection, including quick relief of the pressure in the injection line at the end of the injection period.

The illustrations show principles and details of combustion-chambers, injection pumps and spray nozzles of many representative designs.

INJECTING the fuel at exactly the right moment and mixing it uniformly with the air that is already in the combustion-chamber is the task assigned to the fuel-injection device of the compressorless Diesel engine. It is highly essential that the shape of the combustion space and the characteristics of the injected spray be closely correlated.

Close harmony between the shape of the combustion-chamber and the form of the fuel spray is not of such paramount importance in Diesel engines of the air-injection type. The air, forced into the combustion-chamber with approximately the velocity of sound, creates sufficient turbulence in this space to bring about a homogeneous mixture of air and fuel.

PART 1—COMBUSTION-CHAMBERS

Typical combustion-chambers of Diesel engines employing air injection are shown in Fig. 1. Injected air is dispensed with in the solid-injection oil-engine, thus sacrificing its turbulent effect. It is therefore necessary, if the fuel is to be injected by means of a pump and nozzle alone, to make some provision for turbulence

[2] M.S.A.E.—Vice-president, Robert Bosch Magneto Co., Inc., Long Island City, N. Y.

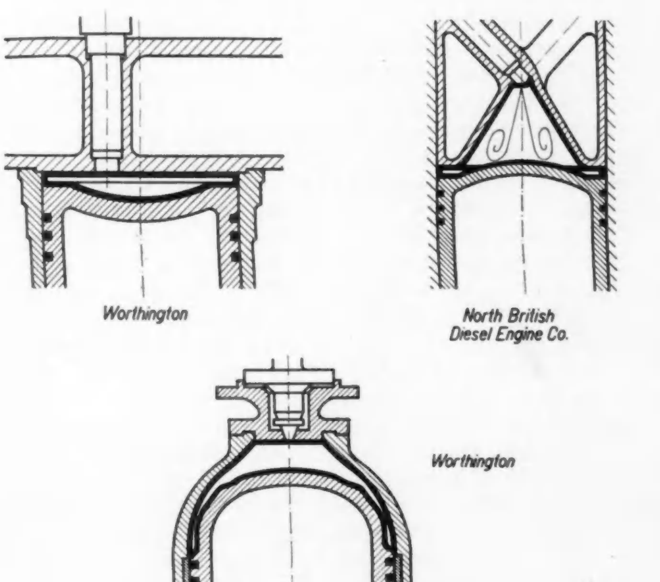


Fig. 1—Combustion-Chambers of Air-Injection Engines

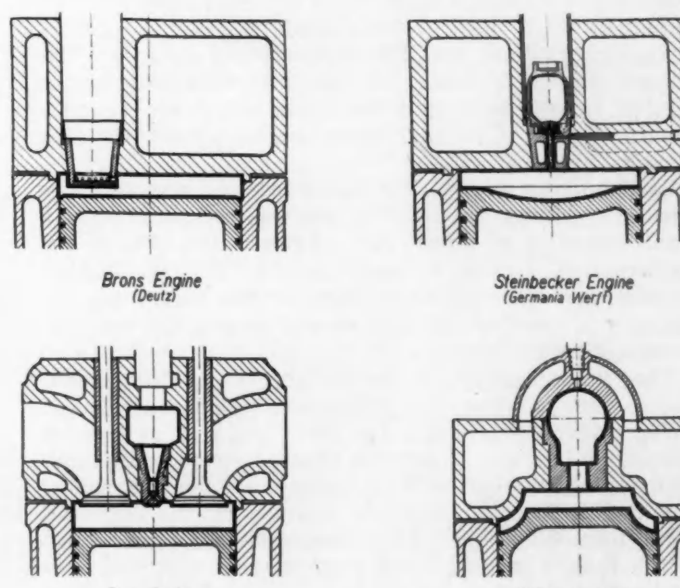


Fig. 2—Typical Precombustion-Chamber Designs

similar to that caused by the injected air in the full-Diesel engine.

Fundamentally, there are two different types of solid-injection oil-engines: (*a*) engines employing a precombustion-chamber and (*b*) engines using the direct-injection system. Engines of the hot-bulb class will not be considered in this paper, as they are steadily losing ground to the solid-injection engine.

Engines Having Precombustion-Chambers

In the precombustion-chamber type of engine, the fuel is injected into a chamber inserted in the cylinder-head and from there is blown into the main combustion space, directly over the piston, by the initial pressure caused by partial combustion of the fuel. The precombustion-chamber is an almost entirely closed space, connected with the cylinder space by one or more small holes. The fuel is not injected directly into the main combustion space. Fig. 2 shows several precombustion-chambers of typical forms, those used in the Brons, Steinbecker, Benz, and Fairbanks-Morse engines. The Brons engine is made by the Motorenfabrik Deutz Aktien Gesellschaft, and the Steinbecker by the Germania Werft. The Bethlehem engine is also in this class.

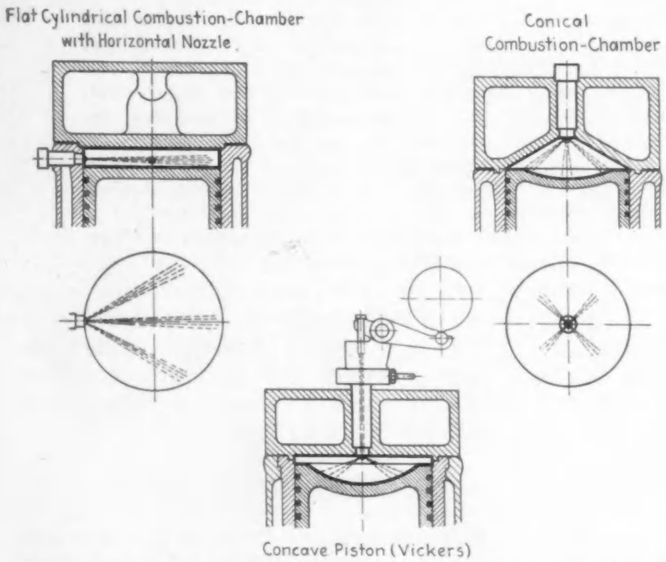


FIG. 3—COMBUSTION-CHAMBERS DEPENDING UPON SPRAY ATOMIZATION

In the Brons engine, the fuel is injected at a very low pressure during the suction stroke, together with a small quantity of fresh air. Toward the end of the compression stroke, a small portion of the fuel is burned, and the resulting pressure rise forces the remainder of the fuel through several small holes into the main combustion space.

The characteristics of the Steinbecker engine, shown also in Fig. 2, is that the precombustion-chamber is not cooled and only as much fuel is introduced as can be completely burned. A narrow channel connects the precombustion-chamber with the main combustion space. The fuel is injected into this channel by the injection valve, toward the end of the compression stroke. Part of the fuel is carried by the air current into the precombustion-chamber, where it ignites and burns. The pressure rise in this chamber effects a reversal of the direction of the flow in the connecting channel and blows the fuel, which is still being delivered by the pump, into the combustion space.

The engines of Steinbecker, Benz, Deutz, and Fairbanks-Morse are similar in effect. The fuel is injected into the precombustion-chamber about 10 to 20 deg. before the upper dead-center position of the piston, the exact time depending on the engine speed, at a pressure of 60 to 80 atmospheres or 900 to 1200 lb. per sq. in. Part of the fuel burns in the precombustion-chamber. This causes a rise of pressure, which injects the mixture of burned and unburned fuel into the main combustion space.

It is not desirable to have a uniform mixture of fuel and air in the precombustion-chamber. On the contrary, only as much fuel should be mixed with this air as can be burned completely by it. The remainder of the fuel should be brought very near to the hole or holes connecting with the main combustion space, so that all of it is forced into the combustion space by the burned gases in the precombustion-chamber. The injection valve or nozzle must have a definite characteristic to be suitable for services in a precombustion-chamber. It must have a solid jet with good depth of penetration to bring the major part of the fuel to the desired spot in the precombustion-chamber, but the outer edge of the jet must be finely atomized and mixed with the air in the chamber.

Engines of the precombustion-chamber type do not start on compression alone, as the surface of the precombustion-chamber is relatively large and quickly dissipates the heat of compression. These engines need starting aid in the form of a glow-plug or punk. Large engines sometimes employ an auxiliary starting injector which delivers fuel directly into the main combustion space.

Engines Having Direct Injection

The fuel is injected directly into the combustion space of direct-injection engines and mixed with the air, either by the action of the finely atomized spray of the nozzle alone or by the use of suitable air turbulence in addition. Engines having auxiliary air-chambers fall into a special class of direct-injection engines. The combustion-chamber is so shaped and arranged that the air is carried to the fuel jet during the combustion period. Therefore we may subdivide engines with direct injection into (*a*) those which depend solely on spray atomization, (*b*) those which atomize the spray by air whirls and (*c*) those having auxiliary air-chambers.

Spray Atomization.—In engines which show little movement of the air during the injection period, the formation of the mixture depends entirely on the nozzle. The fuel must be atomized in sufficiently small particles and distributed uniformly in the combustion space. A few typical examples of this type of engine are shown in Fig. 3. The fuel is injected into the flat, cylindrical combustion-chamber by means of a horizontal nozzle with three or four orifices. The nozzle must be arranged so that the jets are directed fairly close to the piston-head but without touching it, so that the air is carried through the partially burned fuel fog during the down stroke of the piston. If the jets were directed close to the cylinder-head, the air would expand without coming into contact with the fuel. Into the engines having the cone-shaped combustion-space or the concave piston, the fuel is injected by nozzles having three to seven orifices, according to the size of the engine. The jets are directed at such an angle that the fuel will

come into contact with the largest possible volume of air without striking cool walls.

Engines of this type have the combustion spaces and sprays made to conform precisely to one another. We may assume, however, that zones of different pressures are created as a result of partial combustion being the injection period. These pressure differences will cause turbulence in the combustion space and thereby mix the fuel with the air.

Spray Atomization with Air Whirls.—The volume of the fuel to be injected during each pressure stroke of the pump is rather small in comparison with that of the combustion space. If this quantity of fuel were to be mixed uniformly with the air by the action of the nozzle alone, the holes in the nozzle would have to be rather numerous for most of the combustion-chamber forms. The size of the holes would then be rather small and the pressure required to obtain the necessary depth of penetration of the finely atomized fuel would be very high. Several designs have been made to impart to the air in the combustion-chamber a rotary or whirling motion, in order to be able to use larger holes and yet obtain a good mixture of fuel and air. We may distinguish between engines in which the air currents are geometrically definable and engines with eddy currents of air or air whirls. The former type is represented by the engines of Hesselman, Junkers and Krupp, shown in Fig. 4.

In the Hesselman engine, the central portion and the circumference of the piston-head are raised so as to obtain a shape which harmonizes closely with the form of the fuel jet. The circumferential collar of the piston is intended to prevent the fuel from striking the comparatively cool cylinder-walls. This feature is of special importance in small engines. Hesselman shapes his inlet valve in such a way as to impart to the incoming air a rotary motion, to aid further in obtaining a good mixture and complete combustion. The speed imparted to the air should be such that the air will move from one fuel-jet to the next during one injection period. The most favorable shape of the deflector plate at the valve must be determined by trial. Krupp employs a combustion space similar to that of Hesselman and also imparts a rotary motion to the air by means of a deflector plate at the inlet valve. Krupp, however, directs the fuel jets to the piston-head, which is equipped with an insert in the form of a mushroom, as shown in Fig. 4. The plan is that, when the fuel jet strikes the insert, the core of the fuel jet will atomize into a fine fog.

The Junkers two-cycle engine, with its double-opposed pistons, has a flat, cylindrical combustion-chamber into which a finely atomized jet is injected at high pressure through an open nozzle. A tangential arrangement of the scavenging slots, as seen in Fig. 4, gives to the air a rotary motion which persists throughout the compression stroke and thus distributes the injected fuel uniformly in the combustion-chamber.

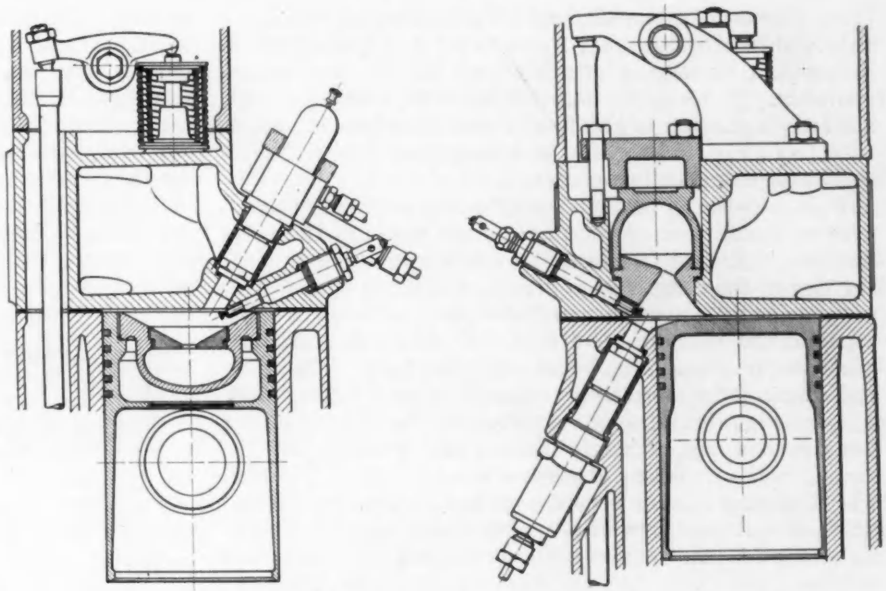


Fig. 6—Auxiliary Air-Chambers

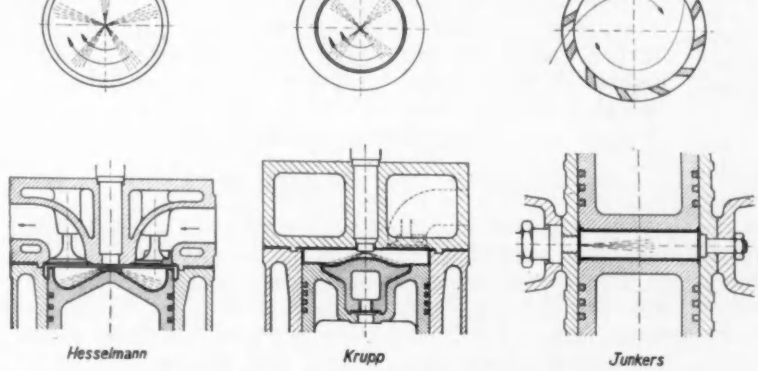


Fig. 4—Combustion-Chambers for Spray Atomization Having Air Whirls

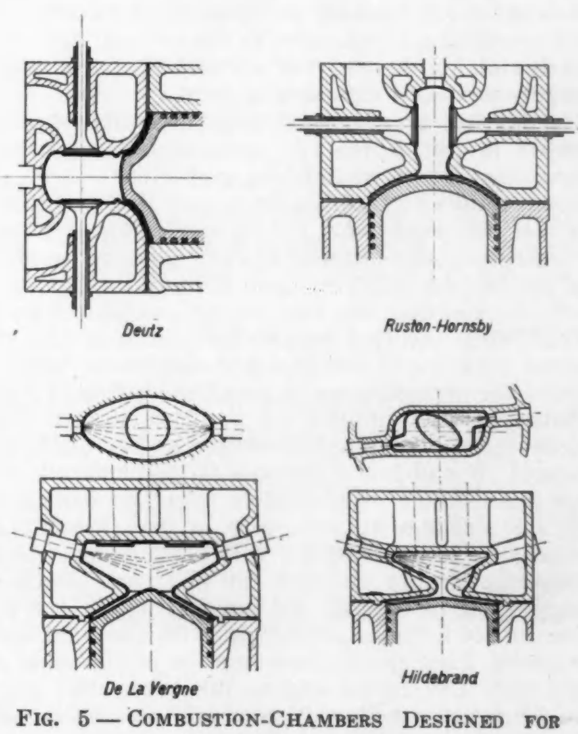


Fig. 5 — Combustion-Chambers Designed for High Turbulence

Agitation by Other Means.—Turbulence of the air is obtained in other engines by building a displacer on the piston and arranging constrictions in the combustion-chamber. Toward the end of the compression stroke, a strong agitation is obtained thereby, as can be readily seen from Fig. 5, in which several typical forms of such combustion spaces are shown.

Fuel is injected into the Deutz horizontal-cylinder engine centrally toward the piston-head through the valve chamber, which also forms the combustion space. Near the end of the compression stroke, the air is forced with great velocity from the annular space between the piston and the cylinder-head into the valve chamber, and mixes with cyclone-like effect with the fuel. The eddying effect of the constricted space, however, is very difficult to control, and small changes in the dimension of the ring slot lead either to undesirable throttling of the air current or else to a quick ebbing of the air whirl. The displacer piston becomes rather hot in high-speed engines and prevents the engine from operating continuously for long periods. This engine, therefore, has not been popular.

An arrangement quite similar to the Deutz engine is employed in the Ruston-Hornsby vertical engine, also shown in Fig. 5. A constriction between the valve chamber and the engine cylinder prevents immediate equalizing of the pressure between the two spaces during the compression stroke and thus causes a thorough whirling of the contents of the valve and combustion-chamber.

The Price engine, built by the De La Vergne Co., has a combustion space in the shape of a double cone, as indicated in Fig. 5. The axes of the two cones are inclined, and a nozzle is located at the apex of each cone. The nozzles have an orifice containing a central pin with helical grooves which impart a wide angle to the spray. The combustion space is connected with the cylinder space through a small, round opening. As the piston forces nearly all the air from the cylinder space through the neck into the combustion space during the compression stroke, lively eddy currents are generated therein. This condition is enhanced by the reversal of the motion of the piston, so that the air and fuel are most thoroughly mixed by this arrangement.

A similar arrangement is used by Hildebrand. As shown in Fig. 5, the two spray cones are so disposed that they do not impinge on each other. An apparent disadvantage of both the Price and Hildebrand engines is that they need two injection nozzles for each cylinder.

Auxiliary Air-Chambers.—The mixture is prepared, in the engines which we have discussed so far, by properly distributing the fuel in the available combustion air. When the fuel burns, the volume of the gas becomes greater and any fuel particles which have not yet found the necessary air in which to burn have a smaller chance to find unused air for combustion. Enough means have been found to obtain a very uniform mixture of air and fuel in engines with comparatively narrow speed-range by a suitably arranged motion of the air, but a change in the velocity of the air results either in mixture of the fresh air with burned gas or in an incomplete mixture of fresh air and fuel. Both conditions result in the fuel not burning within the desired time or not burning completely, with resultant decrease in power, high specific consumption of fuel, and smoky exhaust. The Diesel engine for automotive purposes must produce a uniformly good mixture and an exhaust free from smoke throughout its speed range, and it is rather difficult to comply with this condition in engines such as have been described in the foregoing. As the motion of the air cannot be controlled as desired throughout the entire range of speed, it is possible that part of the injected fuel may be blown into a zone of burned gases and will then burn slowly and imperfectly or not at all.

In engines having an auxiliary air-chamber, the fuel is not distributed to the available air, but the air is distributed to the fuel in a well-regulated manner during the entire period of injection and in a quantity sufficient to provide for complete combustion. This effect is obtained in the Robert Bosch Acro engine by subdividing the combustion space into three different parts: the air chamber, the funnel and the cylinder space.

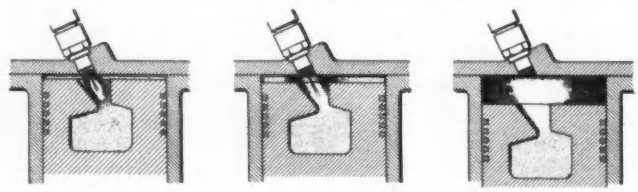


Fig. 7—Action of Auxiliary Air-Chamber

Fig. 6 shows two forms of this engine. The air chamber and funnel are built into the piston in the one at the left, while they are located in the cylinder-head in the style shown at the right. The piston is brought very close to the cylinder-head at top dead-center in both cases. The air chamber and the funnel are connected by an orifice of small size. The combustion cycle of these engines is shown in Fig. 7. The air flows from the cylinder space into the auxiliary chamber during the compression stroke, and the fuel is injected shortly before the piston has reached top dead-center. The fuel ignites in the funnel and combustion takes place at this point. Upon reversal of the piston motion, the space above the piston is enlarged and the pressure is decreased. However, a very high pressure still prevails in the air chamber, so that a strong blast of air is ejected through the orifice of the funnel into which the fuel is being injected until the piston has traveled about 15 deg. past top dead-center. This current of air feeds the flame in the funnel and results in complete combustion of the injected fuel. The gases formed during combustion escape into the continually increasing cylinder space outside the funnel. The burned gases, therefore, do not interfere with the process of combustion. Engines of this type have been operated between 400 and 3000 r.p.m. with smokeless exhaust, good power output and little surplus of air.

PART 2—INJECTION VALVES

The function of the injection valve is to inject the fuel into the cylinder of the engine and at the same time to give the jet or spray a shape to conform with the contour of the combustion-chamber. As there are many types of solid-injection engines, differing widely in combustion-chamber design and in the method of burning the fuel, a variety of injection valves with different spray characteristics are in use. While the in-

jection valves used in air injection differ very little in their construction, many types of injection valves or nozzles are used in solid-injection oil-engines. This is because virtually every type of engine and usually every size of cylinder requires its own design of nozzle.

Injection nozzles are of either the *open* or the *closed* type. A nozzle is of the open type if no means are provided within or near the nozzle to arrest the flow of the fuel. A nozzle is termed closed if it contains a spring-loaded valve near or at the orifice. With the open type, the injection is controlled entirely by the fuel-pump, whereas the closed type is controlled mechanically by cam action or hydraulically by the fuel pressure.

General Principles of Nozzle Design

The designer must know by what means he can influence the shape of the spray, its power of penetration and the degree of atomization in order to select the correct nozzle for a given combustion-chamber or to shape the combustion-chamber to conform to a spray of given characteristics.

The penetration of the spray must be well defined to produce an evenly distributed mixture. The minute globules of fuel must penetrate far into the compressed air, but they must not strike the piston or the cylinder-wall, at least not before they have been ignited. Therefore the depth of penetration of the spray must be adapted to the form of the combustion space. Roughly speaking, we may say that the penetration of a spray depends on the length of the nozzle orifice, the diameter of the orifice outlet and the pressure of the fuel. This penetration increases with increasing ratio of the length of orifice to its diameter.

The degree of atomization of the fuel is equally important. Atomization is favored by high pressure and by decreasing the ratio of the length of an orifice to its diameter. However, other means are available for atomizing the fuel; for instance, the application of spiral flutes which impart a rotary motion to the fuel jet. The centrifugal force of this whirling motion overcomes the cohesion between the particles and breaks them up into a finely atomized spray. Fine atomization is also obtained by causing two fuel jets to impinge on each other. Still another way to obtain a sufficiently atomized spray is by so-called lip nozzles, in which the orifice consists of an extremely fine slot. Other methods of influencing the form of the spray will be mentioned in connection with the constructional features of various nozzles.

The first step in designing a multiple-hole nozzle for a given combustion-chamber is to determine at what angle the holes must be arranged, the main consideration being to give the individual jets the opportunity of coming in contact with the largest possible volume of air. Only this one factor can be determined independently. This and the factors in the following list are so closely inter-related that choosing one or more of them influences all the others: (*a*) number of orifices, (*b*) diameter of each orifice, (*c*) injection pressure, (*d*) depth of penetration, (*e*) spray angle of each individual jet and (*f*) degree of atomization.

The number of orifices must be considerable to distribute the fuel uniformly; but the number is limited by the condition that the diameter of the hole must not be so small as to cause insufficient penetration. The injection pressure must remain within that range which assures good atomization and sufficient penetration throughout the entire period of injection. Finally, the fuel must be injected into the combustion-chamber in as short a time as possible.

The basic equation for calculating a fuel nozzle is

$$Q = vatK \qquad (1)$$

In this equation

$$t = \Theta/6\eta$$

and

a = Total cross-section of nozzle holes, in square millimeters
K = Discharge coefficient, ranging between 0.7 and 0.8
N = Speed of engine, in revolutions per minute
Q = Quantity of fuel, in cubic centimeters per stroke
t = Period of injection, in seconds
v = Velocity of fuel, in meters per second
Θ = Period of injection, in degrees of crankshaft angle

The velocity v must be sufficient to give the necessary depth of penetration, and it depends on the injection pressure p. Its relation is expressed by the equation

$$v = 15\sqrt{p} \qquad (2)$$

in which p is the pressure in atmospheres.

The injection pressure used in connection with multiple-hole nozzles is 250 to 300 atmos-

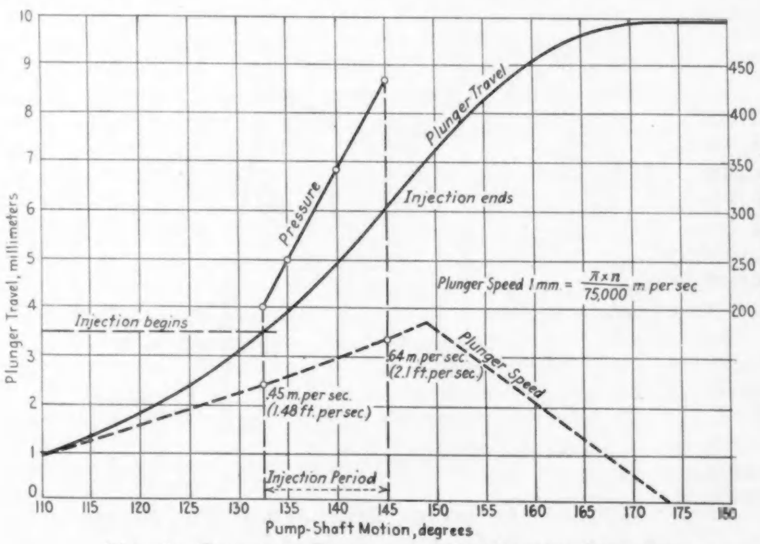


FIG. 8—PLUNGER TRAVEL AND INJECTION PRESSURE

Diagram for a Four-Cycle Engine Running at 900 R.P.M. The Nozzle Has Five Orifices, Each of 0.010 In. The Diameter of the Pump Plunger Is 10 Mm. (0.394 In.)

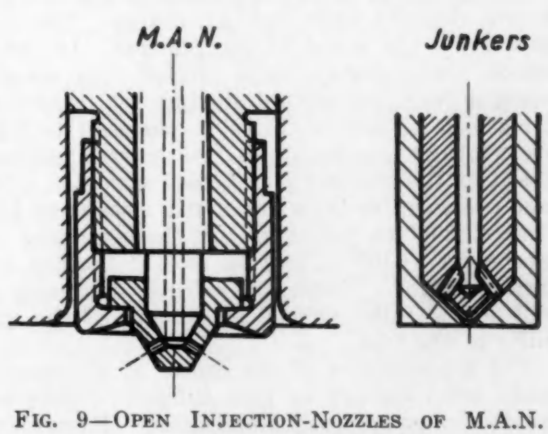


FIG. 9—OPEN INJECTION-NOZZLES OF M.A.N. AND JUNKERS ENGINES

pheres, or 3500 to 4500 lb. per sq. in. The total cross-section of the nozzle orifices can be calculated by substituting the desired period of injection, in degrees, in equation (1).

Rising Injection Pressure is Desirable

It is assumed for these calculations that the velocity with which the fuel is injected remains the same during the entire injection period. However, to obtain a good mixture and smooth running of the engine, it is desirable to inject the fuel at a gradually increasing rate of speed, which condition is brought about by causing the plunger to move at a correspondingly increasing rate of speed. The injection pressure, therefore, will be different during each time element of the injection period.

The low injection-speed at the beginning causes the first globules to travel only a little distance into the combustion space, and they ignite and burn in the proximity of the nozzle. The following fuel globules, which enter with an increasing rate of speed, penetrate farther into the combustion-chamber, force their way through the flame zone and reach fresh air, where they can burn. If the injection velocity were held constant, the fuel injected toward the end of the injection period would remain in a space already filled with burned gases of the fuel that was injected at the beginning of the injection period. Combustion of these fuel particles would not then be possible at once, as they would reach zones of fresh air and begin to burn only during the progress of the expansion stroke.

The injection pressure at each time element of the injection period can be calculated from the equation

$$p = \frac{W_s}{2g}\left(\frac{Av_k}{Ka}\right)^2 0.1 \qquad (3)$$

where

A = Cross-section of pump plunger, in square millimeters
g = Acceleration due to gravity
p = Pressure, in atmospheres
V_k = Speed of plunger, in meters per second
W_s = Specific weight of fuel

The velocity with which the fuel leaves the nozzle is then given by the equation

$$v = \frac{Av_k}{Ka} \text{ or } \frac{D^2v_k}{Kd^2} \qquad (4)$$

where

D = Diameter of the pump plunger, in millimeters
d = Diameter of the nozzle hole, in millimeters

A graphic illustration of the mathematical relations is given in Fig. 8. The form of the full-line curve, indicating the travel of the plunger in relation to the cam travel, depends upon the cam design. The dotted line represents the speed of the plunger. In the case for which these curves were plotted, the speed of the plunger was accelerated during the injection period from 0.45 m. per sec, (1.44 ft. per sec.) to 0.64 m. per sec. (2.10 ft. per sec.). A few degrees farther on, the speed of the plunger is retarded abruptly. The injection pressure for the given nozzle rises from 205 atmospheres (3000 lb. per sq. in.) at the beginning to 435 atmospheres (6400 lb. per sq. in.) at the end of the injection period. These are calculated pressures, which will not be fully realized on account of the compressibility of the fuel.

The cross-section of the orifice of an open nozzle is made small enough so that sufficient back-pressure is created to assure good atomization. Examples of open nozzles used in M.A.N. and Junkers engines are shown in Fig. 9. The structural simplicity of the open nozzle, having no restriction of the flow of fuel between the pump and the nozzle, brings with it a certain disadvantage because of the compressibility of the fuel.

When the delivery of the pump is finished, the fuel line between the pump and the nozzle is under a pressure of 300 to 400 atmospheres, depending on the restrictive effect of the nozzle hole. Although the pump has finished its delivery, the fuel will continue to flow from the nozzle until the pressure in the fuel line is equal to the pressure prevailing in the combustion-chamber. It is evident, therefore, that the volume of the fuel line must be as small as practicable. The compressibility of the fuel is about 0.0001 of its volume for each atmosphere of pressure increase. Assuming the volume of fuel in the connecting line between pump and nozzle to be 3 cc. or 3000 cu. mm. (0.183 cu. in.), and further assuming an injection pressure of 340 atmospheres and a combustion pressure in the combustion-chamber of 40 atmospheres, the pressure drop between the fuel line and the combustion space is 300 atmospheres. Therefore 3000 × 300 ÷ 10,000 = 90 cu. mm. (0.0055 cu. in.) will flow from the nozzle before the pressure in the cylinder is reduced below that in the combustion-chamber. During the expansion stroke, the cylinder pressure will drop to one atmosphere, and a further flow of 3000 × 40 ÷ 10,000 = 12 cu. mm. (0.0007 cu. in.) will take place. This fuel is injected into the combustion-chamber at decreasing pressures, so that the atomization is imperfect and therefore complete burning cannot be effected.

Most of this dripping of fuel can be eliminated if an amount of fuel equal to that which normally would drip from the nozzle into the combustion-chamber because of expansion is withdrawn from the fuel line by some suitable action of the pump, such as will be described later. In spite of this action of the pump, oscillations may occur in the pressure line which will result in some dripping of fuel from the nozzle, for which there is no ready remedy.

Open and Closed Nozzles Compared

A comparison of the action of an open and a closed nozzle, under the simplified condition that they are in-

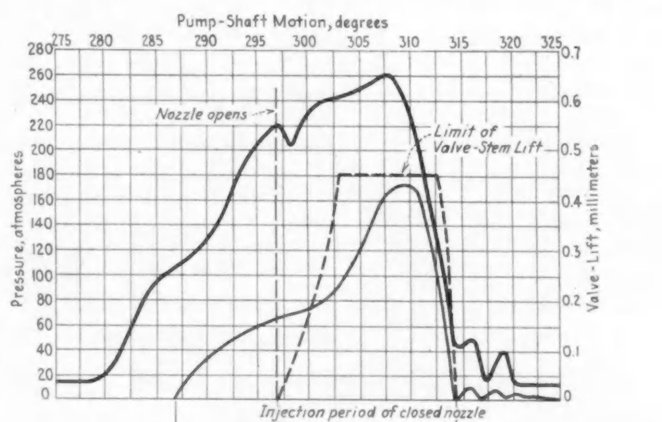


FIG. 10—ACTION OF OPEN AND CLOSED NOZZLES

Comparison Is Made on the Basis of Discharging into Air at Atmospheric Pressure. The Heavy Curve Represents the Pressure in the Fuel Line with Closed Nozzle and the Light Curve Represents the Same for the Open Nozzle. The Valve Lift Is Shown by the Dotted Curve

jecting into air at atmospheric pressure instead of at normal compression pressure, is given in Fig. 10. The open nozzle used has five orifices, each 0.018 in. in diameter. The fuel lines are 39 in. long and 0.100 in. inside diameter. The pump is operated at 600 r.p.m. and withdraws 75 cc. (0.0046 cu. in.) of fuel from the line when the bypass opens, so that the pressure in the line drops immediately to zero. In spite of this, the open valve continues to inject fuel for about 15 to 20 deg., because of the oscillations or swinging of the fuel in the line.

Under the same conditions, the closed nozzle opens at a pressure of 220 atmospheres and closes when the pressure falls below 200 atmospheres. After the bypass of the pump opens, the pressure in the fuel line decreases to 40 atmospheres by the time the fuel valve closes. The surges which now occur in the fuel line are not violent enough to open the valve again, so no additional fuel is discharged.

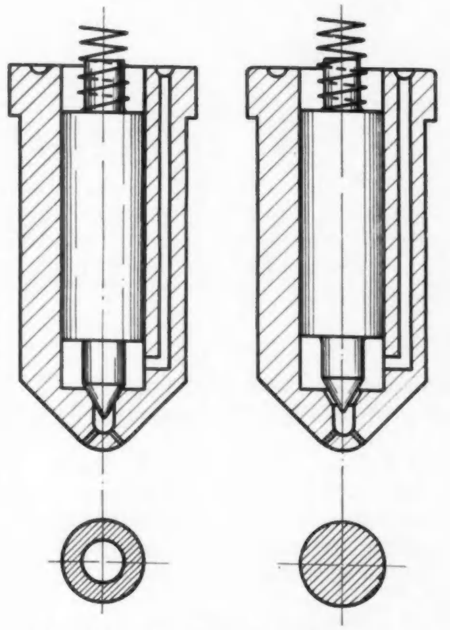


FIG. 11—DIFFERENTIAL ACTION OF CLOSED NOZZLE

The Annular Figure at the Left Indicates the Area on Which the Injection Pressure Acts To Open the Nozzle; the Circle at the Right Indicates the Area on Which the Pressure Acts To Hold the Valve Open

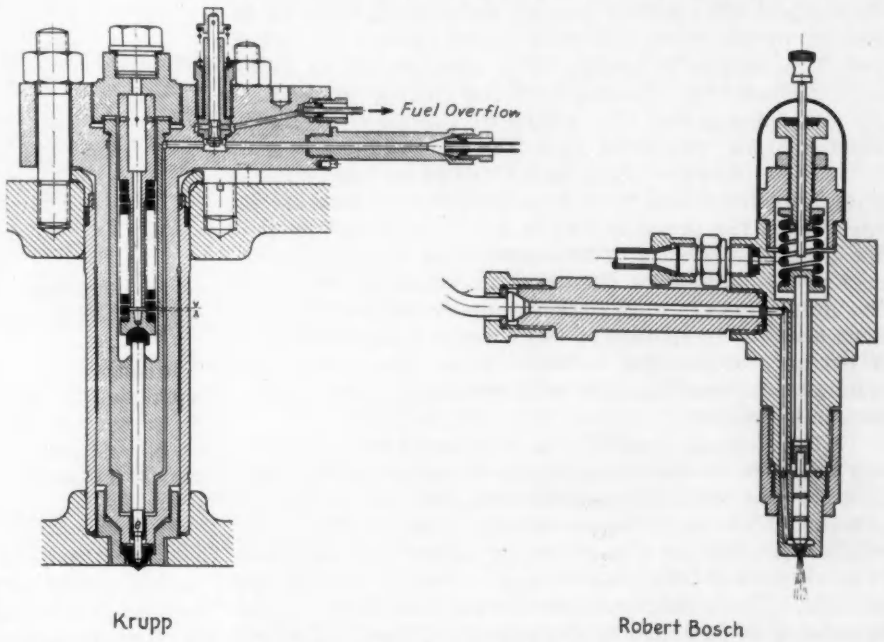


FIG. 12—INJECTION NOZZLES EMBODYING HYDRAULICALLY OPERATED VALVES

The Needle Lift in the Krupp Valve, Shown at the Left, Is Approximately 3/32 In.

Another feature worth mentioning is that the pressure rise for the open nozzle begins 6 to 10 deg, later than for the closed nozzle. This is because the pump has first to replenish the loss due to the surges in the fuel line before pressure can be built up.

The foregoing points the way to the practical application of the open nozzle. The pump and nozzle must not be connected by a long tubing and are best built into one unit. If the pump is to be driven from the camshaft of the engine, it is of advantage to place an individual pump adjacent to each cylinder, so that the fuel lines shall be as short as possible and of equal length.

With decreasing speed of the engine, the period of injection in degrees will remain the same but will increase as measured in seconds. For instance, at one-half the normal speed of the engine the time of injection is twice that when the engine is running at full speed. For a constant-injection angle, therefore, the speed of the injection decreases to one-half normal, according to the following equation, derived from equation (1):

$$v = Q/AtK$$

and the injection pressure to one-quarter normal, according to the following, derived from equation (2):

$$p = v^2/15^2$$

As atomization and depth of penetration are functions of the injection pressure, it stands to reason that the atomization at one-half speed must prove insufficient unless a considerably higher pressure has been provided for the maximum speed of the engine than is necessary for good atomization and depth of penetration. For this reason, engines of the Junkers vehicular type, in which a variable speed is imperative, use pressures between 500 and 700 atmospheres for normal operation. Several manufacturers are still using open-type nozzles, but the disadvantage I have described will undoubtedly cause them to change to closed type.

Closed Nozzles Prevent Dripping

Closed nozzles are used today in the majority of solid-injection oil-engines. The usual construction is a spring-loaded valve at or near the orifice of the nozzle. This valve is generally operated hydraulically by the fuel pressure, although mechanically controlled valves are also in use.

Either type prevents the dripping and consequent prolongation of the time of injection, which are the principal disadvantages of the open nozzle. The closed nozzle makes possible an accurately defined time of injection without dripping. Long pressure lines, when necessary, are not a handicap, so that all the pump units of an engine can be built together in one housing and placed in any convenient location. Nevertheless, there should still be a certain limit to the volume of the fuel lines, and it is desirable that all should be of equal length. Any difficulty because of the compressibility of

the fuel is noticeable only when injecting minute quantities, as I shall presently point out.

The closing pressure of a hydraulically operated nozzle is always lower than its opening pressure, the difference varying according to the design. In other words, a higher pressure is necessary to open the nozzle than to hold it open. When the valve is closed, the pressure is exerted only on the annular area, as shown at the left in Fig. 11; whereas the pressure is effective, when the valve is open, on an area equal to entire cross-section of the valve, as shown at the right. For the same spring pressure, therefore, less hydraulic pressure is necessary to hold the valve in its open position than is required to open it.

This difference in pressure between opening and closing of the valve, in combination with the compressibility of the fuel and the volume of the pressure line, determines the smallest possible amount that can be delivered by the pump for each stroke of the plunger to result in regular injection. For instance, if the difference between the opening and the closing pressure is 50 atmospheres and the volume of the pressure line is 5000 cu. mm. (0.305 cu. in.), then this quantity is $50 \times 5000 \div 10{,}000 = 25$ cu. mm. (0.0015 cu. in.). If the pump furnishes less than this quantity at each stroke, the fuel in the pressure line is not being compressed to the opening pressure of the nozzle and no injection occurs. We then have the peculiar condition in which the nozzle injects only once for every two or three or even every four strokes of the plunger. It is therefore important to keep the volume of the fuel line at the minimum in small engines which operate with high injection pressures.

To inject small quantities at high pressures, the closing pressure of the valve ought to be as near as possible to the opening pressure and the volume of the pressure line ought to be as small as possible. The smaller the engine, the more important this becomes. It is important that the nozzle should close quickly and reliably. The nozzle will close rapidly if the fuel line is relieved of pressure by the pump. If that line is not automatically relieved, the outlets of the nozzle must be of such dimensions that the injection pressure is only little higher than the closing pressure; otherwise, the nozzle will continue injecting air until the pressure in the line has decreased to the closing pressure of the nozzle.

Nozzles of virtually all designs which include hydraulically operated valves are retained in a body by means of a holding nut. The nozzle itself forms the valve seat. The nozzle valve-stem slides in a hardened-steel or cast-iron bushing inserted in the body of the nozzle holder, as shown in Fig. 12.

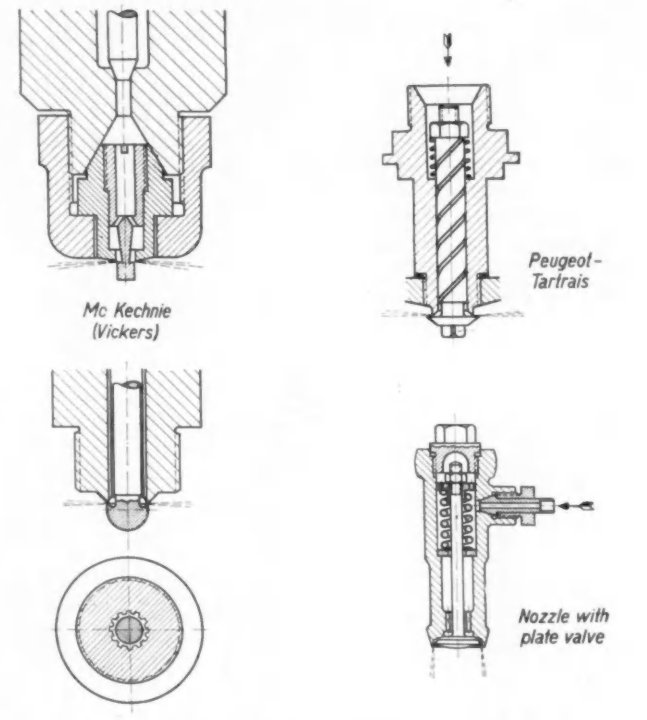
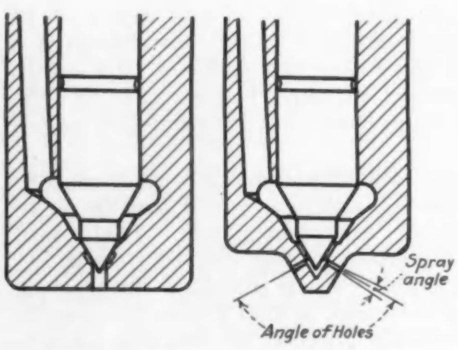


Fig. 16—Circumferential-Orifice Nozzles
The Two Nozzles at the Left Are of Vickers Design

Mechanical Details of Injectors

The valve-stem is lapped in the guide bushing to a fit which makes any form of packing unnecessary; as a matter of fact, packing cannot be used without danger of the stem becoming too tight when the packing is compressed. An air vent should be provided at the uppermost part of the nozzle, to dispose of any air which may accumulate in the fuel line or in the nozzle.

In the Robert Bosch design, the nozzle and guide bushing are integral. The nozzle holder is secured to the cylinder-head by the usual yoke and studs. It contains the loading spring and the device for adjusting



Closed Injecton-Nozzles
Fig. 13 — Single-Hole Nozzle, Closed Fig. 14—Multiple-Hole Nozzle, Open

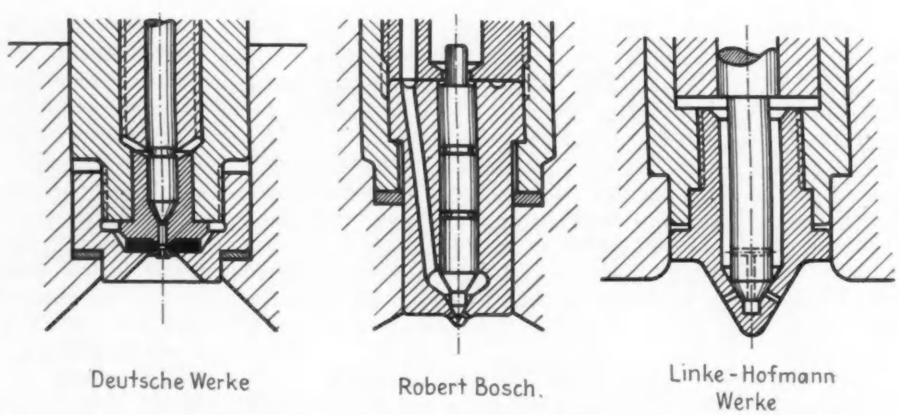


Fig. 15—Multiple-Hole Nozzles, Hydraulically Operated

the spring pressure, and is threaded at its lower end for the holding nut that secures the nozzle proper. The faces of the nozzle and its holder are ground and lapped to assure a good fit and freedom from leakage at any pressure. At the side of the holder are two connections, one for the fuel line and the other to carry off, usually to the service tank, any fuel that may leak past the valve-stem. The loading spring is housed at the upper end of the nozzle holder, which is naturally the coolest portion. The lower end of the spring rests on a cap which in turn rests on the valve-stem proper, and the upper end abuts on the adjusting screw. A protecting cap covers the adjusting device. The holder is also equipped with a feeler pin which passes through a central hole in the adjusting screw. If this pin is depressed by the finger, the motion of the nozzle stem can be felt. This provides a convenient way to determine whether the nozzle is functioning.

Valve seats of most nozzles are conical; but flat-faced seats are used occasionally, the advantage being that exact centering of the valve-stem is unnecessary. In certain forms of combustion-chamber, the fuel jets must be delivered in definite directions. Nozzles and holders must be located in the cylinder-heads of such engines by dowels.

Nozzle Orifices Classified

Nozzles can be classified as to their orifices as follows: single-hole, multiple-hole, circumferential and pin nozzles.

Single-Hole Nozzles, like that shown in Fig. 13, are those in which the fuel jet is formed by a circular hole in the mouth of the nozzle. The axis of this hole can be the same as that of the nozzle or at an angle to it. The jet of such a nozzle is of conical shape, having an angle from 4 to 15 deg. At angles greater than 12 deg., the uniformity of the cone jet is easily disturbed by any slight inaccuracy in manufacture; and the wider the angle, the more likely is the major part of the fuel to be ejected unevenly. Wider spray angles are obtained by the use of spiral grooves to impart a centrifugal motion to the fuel particles.

Single-hole nozzles, with and without spiral grooves, are used in precombustion-chamber engines and those direct-ignition engines in which the fuel is distributed in the combustion-chamber by strong air-whirls.

Multiple-Hole Nozzles.—For direct-injection engines having flat, tapered or other types of combustion space, with or without whirling of the charge, introduction of the fuel through one hole is inadequate. It is necessary to arrange several holes to distribute the fuel uniformly in the combustion space. Examples of this are the enlarged nozzle of Fig. 14 and the nozzles designed by Deutsche Werke, Robert Bosch and Hesselman, shown in Fig. 15.

Circumferential Orifices are of the lip or the plate variety. As the jets of single and multiple-hole nozzles form a spray angle of 14 deg. at the most, the volume of air reached directly by the fuel is rather limited. With this in mind, some designers have tried to inject the fuel from the nozzle in the form of a plane, a wide-angle hollow cone or a band in order to obtain maximum surface area of the fuel spray. Examples of these are shown in Fig. 16. Vickers, for instance, designed a nozzle the orifice of which is formed by two knife-edges which cause the jet to assume the form of a flat disc. The two knife-edges are arranged very close to each other. There may even be no gap normally, the lip being allowed a very slight downward movement during injection.

The same kind of spray is produced also by the injection valve of Peugeot-Tartrais, in which the spray is given a rotary motion in addition by spiral grooves in the stem.

Another nozzle having a long circumferential orifice is the plate nozzle, in which a suitably shaped plate gives the spray the desired angle.

All of these nozzles cause very finely atomized sprays, but their power of penetration is weak because of the small size of the globules of fuel. A good mixture can be obtained with this type of spray only in small combustion-chambers.

Pin Nozzles are fitted with valves whose ends are furnished with a thin shank or pin, as shown in Fig. 17, the shape of which is made according to the spray angle desired. This pin reaches into the nozzle orifice so that an annular space is formed. By suitably shaping this pin we can have either a hollow cylindrical jet of high power of penetration or a tapered spray with an angle varying from a few degrees to approximately 60 deg. The wider the angle, the better the atomization; but at a sacrifice of penetration. This arrangement permits fine variations in the spray characteristics; for instance, the cross-section of the orifice can be opened gradually during the lifting of the valve-stem if the pin is tapered, or in steps if the pin is made in two cylindrical steps. In this way only a small quantity of fuel is injected at

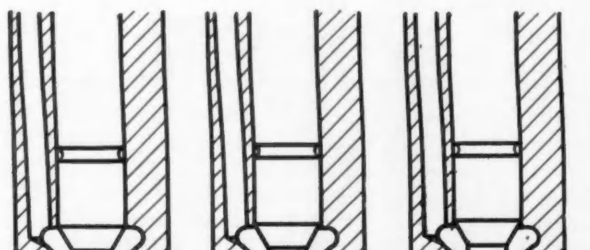


FIG. 17—THREE TYPES OF JET FROM PIN NOZZLES
The Jet from the Nozzle at the Left Is a Hollow Cylinder, That from the Center Nozzle Has a Small Taper of from 6 to 10 Deg. and the Nozzle at the Right Can Be Designed To Give a Taper of from 15 to 60 Deg.

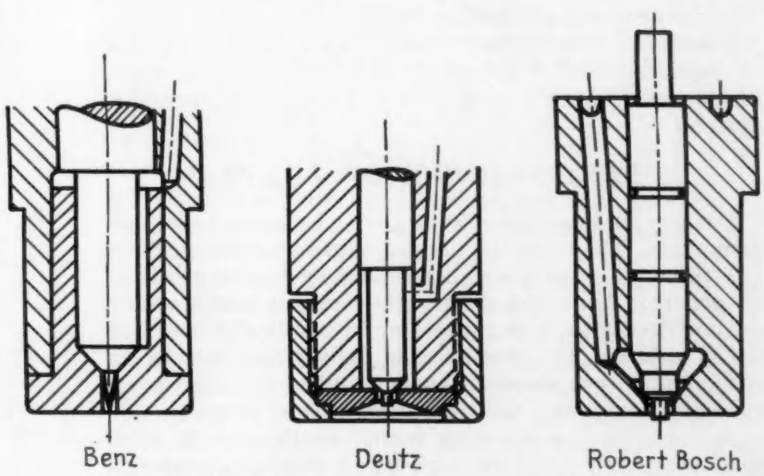


FIG. 18—PIN NOZZLES OF THREE DIFFERENT MAKES

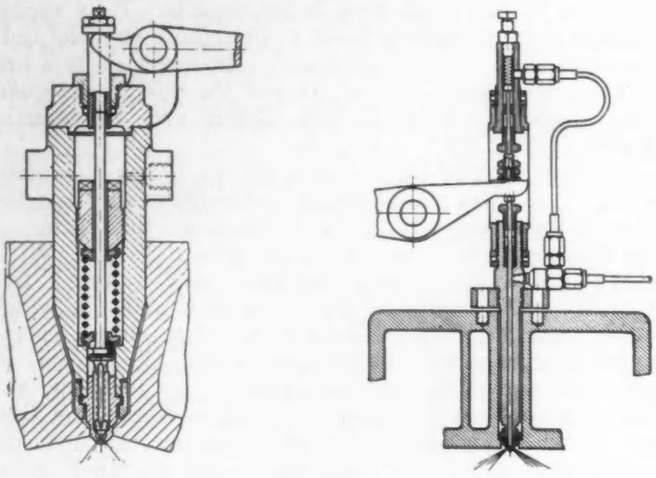


FIG. 19—MECHANICALLY OPERATED NOZZLES

The Fuel Comes to These Nozzles Under a Constant Pressure from a "Common Rail" and the Injection Is Timed by the Mechanical Operation of the Nozzle

first, followed by the major part of the fuel. This procedure prevents a sudden pressure increase in the cylinder and gives smoothness to the running of the engine.

The double-throttling effect of the nozzle, first at the valve seat and then at the nozzle orifice, is responsible for the fact that the pin nozzle works very uniformly and accurately. In addition, the motion of the pin in the nozzle orifice prevents the formation of a carbon crust. The pin nozzle can be used with advantage to replace the single-hole nozzle previously described.

Fig. 18 shows pin nozzles used by Benz, Deutz, and Robert Bosch. The Benz nozzle has a tapered pin. The Heidelberg-Deutz nozzle-plate has a sharp edge, which causes turbulence of the outer surface of the jet. In the Robert Bosch nozzle, the pin extends beyond the orifice in the closed position of the valve.

Mechanically Operated Nozzles.—The mechanically operated valve has been used chiefly in England and America. The fuel is delivered from the pump into a common tank first and from there to the various nozzles. The injection valve is opened by a cam on the camshaft, acting through a lever, not by the fuel pressure. The construction of the valve is similar to that used on Diesel engines with air injection, and the nozzle proper does not differ from the hydraulically operated nozzle. Fig. 19 shows the injection valves of this type used by Vickers and The Western Machinery Co. This method of injecting fuel is known as the common-rail system, or, to use a more suitable term, the constant-pressure system.

PART 3—INJECTION PUMPS

Designs of injection pumps are as numerous as those of nozzles. They may be divided into two main groups: (*a*) injection pumps which deliver fuel to the nozzle at an accurate time and accurately metered and work in conjunction with open nozzles or hydraulically operated closed nozzles; (*b*) pumps that deliver the fuel to an accumulator or reservoir and require no timing or metering features. Consideration will be given in this paper only to the injection pump, as this is the type most commonly used on high-speed solid-injection oil-engines.

Requirements and Principles of Pumps

The injection pump must deliver a small and accurately metered quantity of fuel at the right moment. The delivery must begin precisely at a definite moment and must also finish precisely at the right time. The pressures required in the injection system usually are from 60 to 400 atmospheres and may rise to even 700 atmospheres for some nozzle constructions. All parts of the pump that are subjected to pressure must therefore be made of the finest material, preferably steel.

Fig. 20 is a cutaway drawing of an injection pump. The plunger and the cylinder elements of the pump are hardened and ground, or the cylinder can be made of fine-grained perlitic cast-iron. Formerly it was customary to use packing for the plungers, but the difficulties experienced at high pressures are such that packed pumps are practical only for low-speed engines.

The check-valve and its seat must be exceedingly hard, as they are exposed to very high pressure. The seating surface must be made very small to make the valve leak-proof. The velocity of the fuel through the check-valve is usually very high, and this makes it necessary to limit the lift of the valve. It is also essential that the valve-spring be of liberal dimensions to avoid breakage.

Leakage is best eliminated by hardening and grinding the surfaces of the joints. Where this is not possible, solid copper gaskets must be used.

The operating sequence of the pump plungers should be made to conform to the firing order of the engine by the arrangement of the cams on the pump shaft, to avoid crossing of the fuel lines.

Usually each engine cylinder has a corresponding pump element. In some designs, however, one element of the injection pump serves several cylinders. In such cases, the plunger must make correspondingly more working strokes, and the fuel is directed to the nozzles of the individual cylinders by means of distributing valves. The camshaft and tappets of the pump must be rigidly and liberally designed so that no give or elastic deformation can occur that is sufficient to disturb the injection in any way. This is vitally important.

The roller and pin of the tappet are hardened to with-

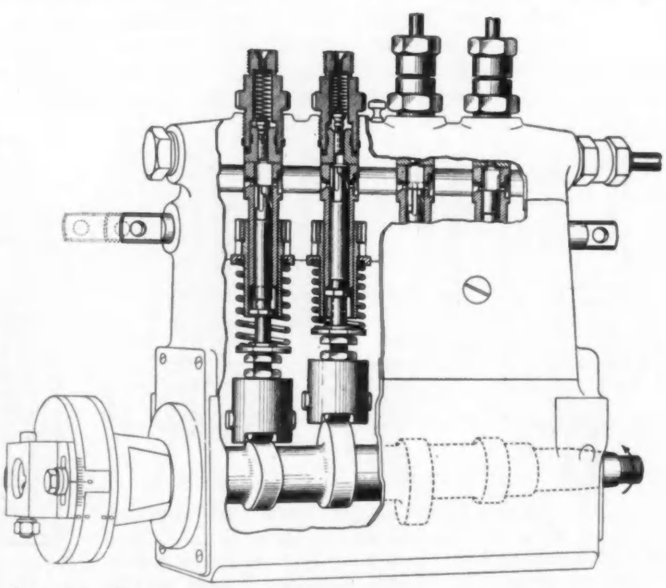


FIG. 20—ROBERT BOSCH QUADRUPLE PUMP FOR TIMING AND METERING INJECTION

stand the high stresses involved. The strength of the tappet retaining spring must be determined according to the contour of the cam and the operating speed. The inertia of the moving parts tends to separate the roller from the cam during the upper part of the plunger strokes. The spring must exert sufficient tension to overcome this inertia.

The amount of fuel injected is usually controlled by the governor. It is desirable that the force necessary for this control be small, so that a governor of small dimensions can be sufficient. This is especially important in connection with fuel-injection pumps for automotive engines which require great speed variation. Practical operation has shown that the governing of the maximum permissible speed of the engine is not sufficient and that control of the engine under no-load condition is just as important. An arrangement providing for this is shown in Fig. 21.

Without such a governor, the engine would tend to race or slow down, perhaps to an absolute standstill,

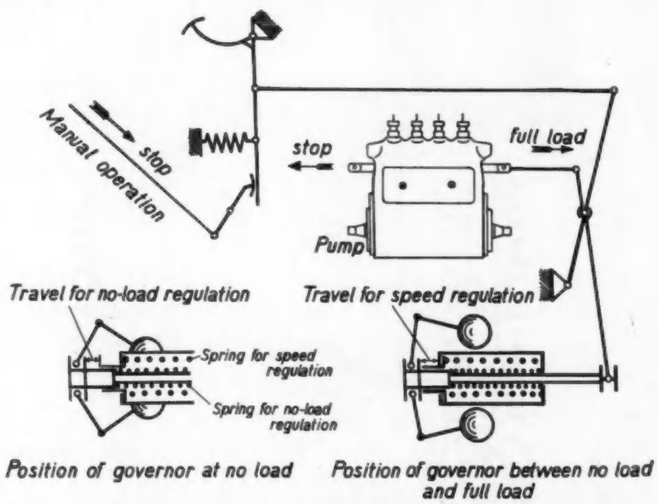


FIG. 21—ARRANGEMENT OF GOVERNOR TO PROVIDE REGULATION FOR BOTH SPEED AND NO-LOAD CONDITIONS

when the friction losses of the engine vary for one reason or another. The operator should be able to influence directly the amount of fuel injected, between no-load and maximum speed, by manual control.

It is advisable to make the volume of all pump and fuel-line spaces which are under pressure as small as possible, for the reason given in connection with nozzles.

Air carried into the pump by the fuel is extremely undesirable. Such air is frequently encountered in automotive service, because air mixes with the fuel in the tank as it splashes back and forth continually This air must be given an opportunity to escape, preferably by passing it through a suitable filter before it reaches the pump.

The pump must be designed so that it has no pockets in which air can accumulate, and the pressure lines must be arranged so that no air cushion is permitted to exist.

Filtering the Fuel

It is imperative that the fuel which comes in contact with the pump elements, with the suction and discharge valves and with the injection valve be carefully filtered. The filter must be fine enough to separate out the small sand and dust particles suspended in the air and which

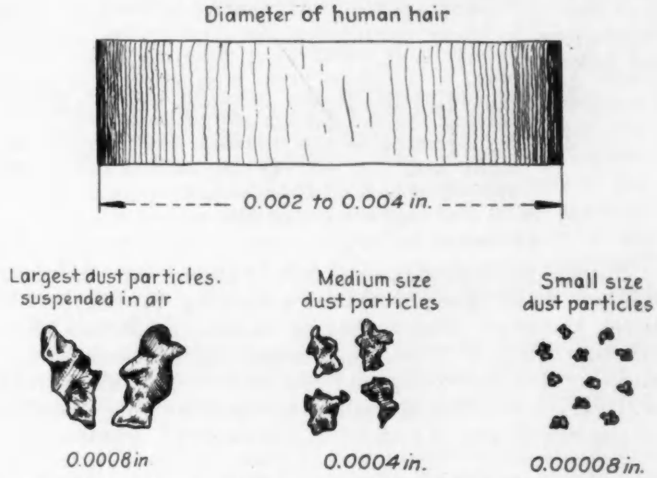


FIG. 22—GRAPHICAL REPRESENTATION OF THE SIZE OF DUST PARTICLES

eventually find their way into the fuel. The size of dust and sand particles suspended in still air has been shown to be from 0.0008 to 0.00008 in. or even smaller. An illustration of the size of dust particles in comparison with the diameter of a human hair is shown in Fig. 22. The best results have been obtained with woven-cloth filters having surfaces as large as possible.

When multiple-hole nozzles are used, particular attention must be paid to the problem of filtering the fuel. The fine holes of the nozzle are easily clogged and the careful designer inserts an additional filtering device directly in front of the nozzle holder. No matter how well the filter cleans the fuel before it enters the pump, there may be minute particles of metal chips in the pump itself or scale in the fuel line which loosen only after a long period of operation. Such an occurrence would result in clogging one or more holes of the nozzle.

Controlling the Quantity of Fuel

Fundamental in the design of the injection pump is the method of controlling the quantity of fuel. This control may be effected in any one of the three ways shown in Fig. 23, as follows:

By a sliding cam.—The stroke or lift of the plunger is varied by means of a cam of suitably varied outline.

By needle regulation.—Part of the fuel entrapped in the pump during the working stroke of the plunger is permitted to escape through a bypass to the fuel intake of the pump. The quantity bypassed, and consequently also the amount of fuel which is permitted to reach the nozzle, is regulated by means of a throttling pin.

By bypass regulation.—The third method is to open a bypass port after a definite part of the plunger stroke, the port being in connection with the fuel intake. In practice, this is done usually by opening a special bypass valve or by opening the inlet valve of the pump for a longer or shorter period before the end of the working stroke of the plunger. Pumps without suction valves, in which the piston itself controls the intake port, have a slanting groove in either the piston or the piston sleeve which registers with an opening in the piston sleeve or piston earlier or later in the working stroke according to the relative angular position of these parts. The excess amount of fuel can then escape from that part of the cylinder space which is under pressure.

These different systems of control permit certain variations in their application, which can be outlined as follows:

(1) The beginning of the injection can be varied, leaving the end always at the same time
(2) The beginning of the injection can remain constant and the end be varied. This is the method of control most commonly used
(3) Both the beginning and the end of the injeection can be varied

Pumps having variable plunger-stroke can use any one of these three methods, according to the profile given the cam. Pumps having needle regulation leave the total time of injection constant for all fuel quantities, but the beginning and end of the injection period will vary somewhat according to the throttling position of the needle and the speed of the engine. Pumps having bypass regulation make possible the use of any one of the three methods.

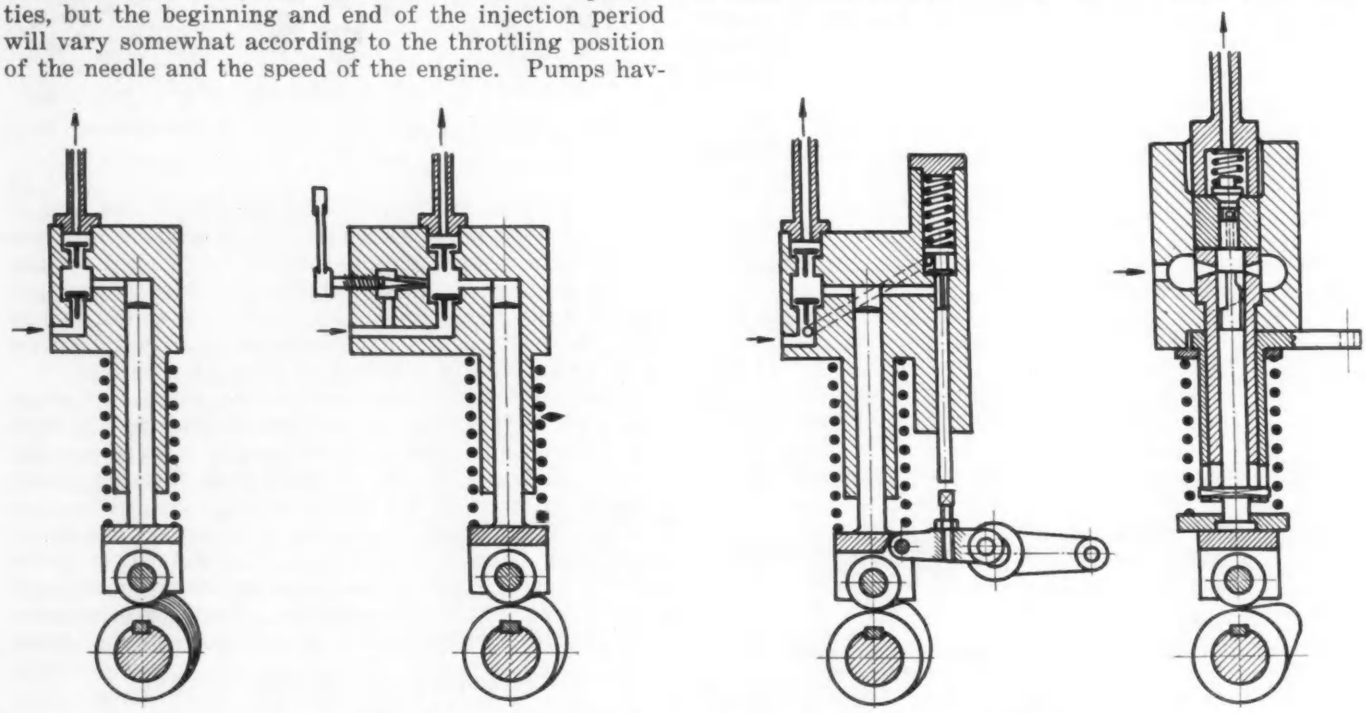


FIG. 23—METHODS OF REGULATING THE DELIVERY FROM A PUMP

The Pump at the Left Is Given a Variable Stroke by Means of a Sliding Cam of Variable Contour. The Second Pump Is Provided with a Needle-Valve Allowing Variable Leakage and Therefore a Variable Net Delivery. The Two Pumps at the Right Have Bypass Regulation, the First by Means of a Valve That Can Be Tripped at a Variable Point in the Stroke and the One at the Extreme Right by a Sloping Groove in the Plunger

Variable-Stroke Fuel-Pumps

Several methods of regulating the quantity of fuel by a variable stroke of the pump are illustrated in Fig. 24. The method which includes a shifting cam makes possible a very simple construction for the pump. The shifting may be either an axial sliding or a double-eccentric arrangement. Another method of regulation is by inserting a wedge in the tappet mechanism to cause variable stroke. The force necessary to change the stroke of the plunger is rather great in this method, because of the pressure against which the plunger has to work; therefore it is seldom applied to pumps requiring pressures greater than 1000 to 1500 lb. per sq. in., because of the excessively heavy governor weights that would be required.

Regulation by means of a sliding cam can be effected by hand or by a governor. Fig. 25 shows a pump of this type for a four-cylinder automotive engine. The camshaft of such a pump requires exceedingly precise workmanship to secure uniform contours and accurate spacing of the cams.

With the shifting eccentric, only a small part of the lift of the eccentric can be utilized. Eccentric regulation is applied only to small two-cycle engines.

The other method of regulation shown in Fig. 24 is by variable leverage. The stroke of the pump is changed by sliding the lower end of the push-rod on the rocking lever.

Bypass Control by Valve

A typical example of a pump having needle-valve control is shown in Fig. 23. The stroke of the piston remains constant, and the fuel which is not needed for injection returns, either to the intake space or by a separate line to the fuel tank, during the upward stroke of the piston. Such pumps are being replaced largely by pumps having mechanically operated bypass control.

Bypasses can be controlled by valves in different ways. Pumps equipped with inlet and outlet valves use the inlet valve for this purpose or else a separate bypass valve is arranged. Pumps having piston valves either are provided with a separate bypass piston or the plunger itself is used for controlling the quantity of fuel. Such pumps work with constant piston stroke.

Diagrams of two pumps having bypass valves are shown in Fig. 26. The same valve is used for both inlet and bypass in the diagram at the left, being pushed open during the pressure stroke of the pump, at a time that is controlled by the governor, to permit the return flow of fuel. The pump shown at the right works in the same way except that a separate inlet valve is provided and the excess oil escaping through the bypass valve is returned by a separate line to the fuel tank.

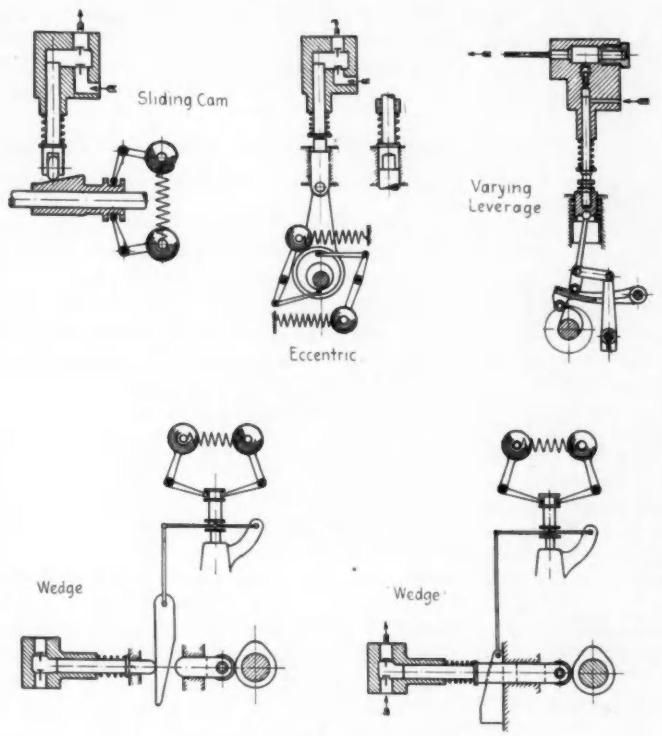


FIG. 24—METHODS OF IMPARTING VARIABLE STROKE TO THE PUMP PLUNGER

The advantage claimed for this construction is that any surges which may occur in the suction line will have no effect at the delivery side of the pump.

Bypass Control by Pump Plunger

Control of the bypass by means of the pump plunger has found considerable favor and is being used extensively. A typical construction of a single-cylinder pump embodying this feature is shown in Fig. 27. Each pump element consists of a cylinder *a* and a piston or plunger *b*. The cylinder is closed at its upper end by a spring-loaded pressure valve *c*, from which the fuel line *d* leads to the injection valve.

In the upper part of the housing is a suction space which is connected with the fuel tank by means of the suction pipe *e*. Two small holes connect the suction space with the pressure space in the pump cylinder. The stroke of the plunger is constant. The upper edge of plunger *b* controls the beginning and the slanted groove controls the end of the fuel delivery. The end of the delivery is reached sooner for a small quantity of fuel than for a large quantity. This is brought about by turning the pump plunger into different positions.

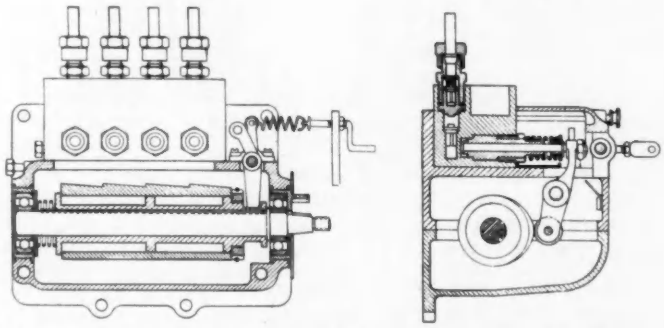


FIG. 25—DEUTZ QUADRUPLE FUEL-PUMP WITH SLIDING MULTIPLE CAM

The pump cylinder is enclosed by a bushing *f*, to the upper end of which a gear segment is fastened. This segment in turn engages with a toothed rack *g*, which is actuated manually or by a governor. At its lower end this bushing has two opposite slots, in which a cross-arm of the piston is guided; the angular motion of the bushing, caused by sliding the control rod, being thereby transmitted to the plunger. No fuel is delivered by the pump when the control rod is at one extreme position; in the opposite position, the maximum quantity of fuel is delivered.

The operation of the pump is shown in detail in Fig. 28. In the lowest position of the piston, the two opposite ports are opened and the cylinder above the piston is filled with fuel.

During the first part of the pressure stroke of the piston, a small quantity of fuel is forced back into the suction space, until the plunger closes both port holes. From then on, the fuel is put under pressure and the pump begins to force it through the check-valve and the fuel line into the injection valve.

Delivery begins as soon as the plunger has covered the ports on the way up and ends as soon as the sloping edge, indicated by the arrow, opens the port hole on the right-hand side and permits the fuel to escape from the pressure space above the plunger, through the groove in the plunger and the port, to the suction space.

In the two views at the left, the plunger is shown in the position for maximum delivery, in which the edge of the helical groove does not open the port hole at all. The next two views show the position of the plunger for medium delivery of fuel, and the one at the right shows the position when no fuel is being delivered.

Relieving Pressure in the Fuel Line

As soon as the slanting edge of the groove in the plunger opens the port hole, the pressure in the pump cylinder is relieved. The pressure which still exists in the fuel line, together with that of the valve-spring, forces the pressure valve to its seat. The fuel line is now closed off from the pump cylinder until more fuel is delivered during the next working stroke.

The check-valve, however, has another important task to perform. It is highly desirable to relieve the pressure in the fuel line in order to obtain a rapid closing

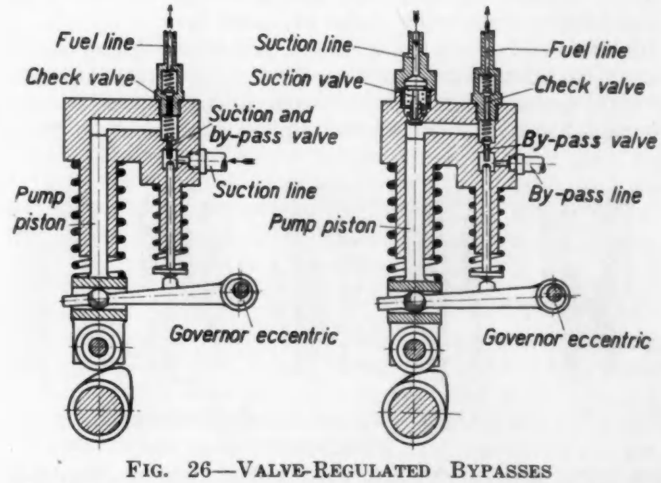


FIG. 26—VALVE-REGULATED BYPASSES

In the Pump at the Left the Inlet Valve Is Tripped to End the Delivery. A Separate Trip Valve Is Provided in the Pump at the Right

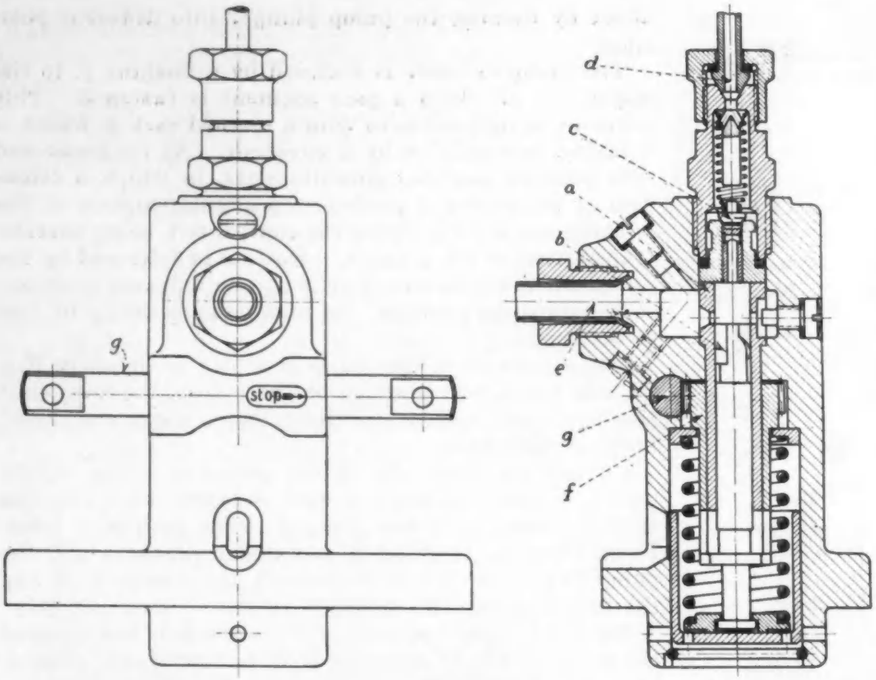


FIG. 27—PUMP IN WHICH PLUNGER ACTS AS BYPASS VALVE

of the injection valve, as otherwise dripping of fuel from the nozzle into the combustion-chamber may occur. A special construction of the check-valve provides this pressure relief in an effective and reliable way, as shown in Fig. 29. During the working stroke of the pump, the valve is raised from its seat and the fuel flows through the hollow stem and the two connecting holes into a ring groove and from there to the fuel line. Adjoining the ring groove is a short cylindrical surface forming a shroud, and above this is the valve-head. When the bypass opens, the valve closes. In doing so, the receding valve-stem causes an increase in the volume of the fuel line by an amount equal to the volume of the shrouded part of this valve-stem. The fuel in the line is in this way suddenly relieved of its pressure, and rapid closing of the injection valve is effected.

A pump such as that shown in Fig. 27 is operated by reciprocating motion provided for in the design of the engine, from the camshaft or in some other suitable way. Pumps of this sort are made in various sizes, the largest delivering 5400 cu. mm. (3.295 cu. in) of fuel for each working stroke. A self-contained pump, such as that shown in Fig. 20, has a camshaft, individual cams and rollers for each pump element. Such pumps are available in sizes up to that required for a four-cycle engine having 280 cu. in. displacement per cylinder and requiring approximately 260 cu. mm. (0.159 cu. in.) of fuel for each work stroke.

Application to Engines for Various Purposes

Since several firms have taken up the design and manufacture of fuel-pumps, the number of manufacturers who are building or experimenting with high-speed solid-injection oil-engines is increasing. It is always rather difficult for engine manufacturers to build the parts for the injection system, as extreme precision and considerable experience are required. Pumps and injection valves are on the market by means of which quantities of fuel down to the volume of a pin-head can be injected and accurately timed, within the desired degrees of piston travel, the spray being finely atomized and given a depth of penetration suited to the engine. This equipment can be operated at engine speeds up to more than 1500 r.p.m. With these available, the designer can concentrate on the main problem of selecting a combustion space most suitable for his particular purpose.

Engines of various types are not all alike suited for various applications; each has a field in which it gives the best results. All the various injection systems and

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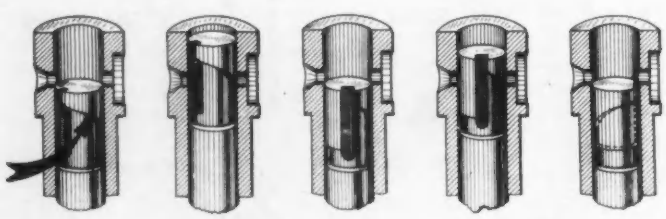


FIG. 28 — REGULATING PLUNGER OF PUMP IN VARIOUS POSITIONS

The Two Views at the Left Show the Position for Maximum Delivery, the Next Two Views Represent Medium Delivery, and No Delivery Is Made When the Plunger Is in the Position Shown in the One View at the Right

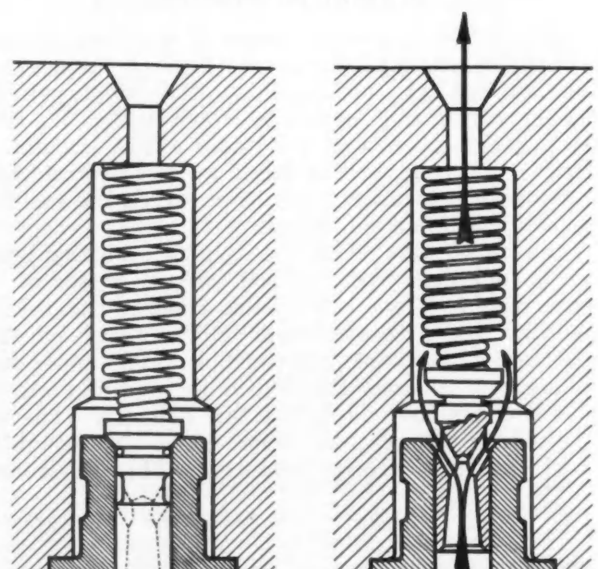


FIG. 29—PUMP OUTLET VALVE PROVIDING RELIEF IN DELIVERY LINE

During Delivery, the Valve Opens to the Position Shown at the Right, Because No Discharge Can Occur Until the Cylindrical Collar under the Valve-Head Is Clear of the Valve Seat. When the Bypass Valve Relieves the Pressure in the Pump, the Valve Returns to Its Seat, as Shown at the Left, Reducing the Amount of Oil in the Delivery Pipe by an Amount Corresponding to the Volume of the Cylindrical-Collar Portion of the Valve-Stem

Six-Cylinder Motor-Truck Engines

By LEWIS P. KALB[1]

TRANSPORTATION MEETING PAPER — *Illustrated with* CHARTS AND PHOTOGRAPHS

DUE MAINLY to the growth of inter-city traffic, motor-trucks are operating at much higher speeds than those of 10 years ago. This has been accomplished mainly by running engines faster, according to the author. It is to this combination of heavy duty and high speed that the six-cylinder engine is particularly adapted, because of its wider power range and greater smoothness of operation. These points of superiority have been disadvantageous in that they make the six-cylinder engine more subject to abuse caused by over-speeding.

It is very essential that the speed of this type of engine be limited in some manner. Engine speed can be limited by means of governors, by restricting engine power and by use of small gear-ratios. All three methods may be used; but the use of the right gear-ratio is to be preferred. This calls for an engine of adequate size, which means that the engine must have the torque necessary for good acceleration with a gear ratio not producing excessive engine-speed. Insufficient displacement is the principal cause of over-speeding engines.

Factors expressing comparative ability and comparative engine-speeds of vehicles are given by the author; also, the load carried per cubic inch of piston displacement. All of them show that the six-cylinder motor-truck engine is being called upon to meet much heavier service than is the passenger-car engine. In the design of a heavy-duty six-cylinder motor-truck engine, ruggedness and reliability must come before other considerations. Lightness and low cost must both be subordinated. Only the best materials can be used, and the extra cost produced by refinements of design generally represents money well spent.

Oil-cooling problems and their solution formed the subjects of the major portion of the discussion. Other subjects related to torque comparisons between four and six-cylinder engines, reduction of traffic impedence by increasing the speed of trucks, and reduction of oil viscosity by high temperatures.

EACH YEAR the traffic on our highways moves faster. This has been going on ever since the inception of motor-vehicle traffic; no one can predict where or when it will end. Legislation, induced by public sentiment, probably will attempt to call a halt in the near future. Even should this succeed, we still have the possibility of super-highways reserved for fast traffic, where speed much higher than any yet attained will not only be permitted but encouraged. It is in the commercial-vehicle field that this trend has been the most marked. The principal reason is the tremendous growth in the operation of intercity motor-trucks and motor-coaches.

Although the amount that commercial vehicles have speeded up in any one year has not been pronounced, a comparison of the speed at which trucks operate today with that considered proper for vehicles of the same capacity only six years ago, is bound to be somewhat impressive. The Motor-Truck Standards adopted by the National Automobile Chamber of Commerce in January, 1923, recommended a maximum speed of 25 m.p.h. for all vehicles operating on pneumatic tires with a total gross-load not exceeding 28,000 lb. For solid tires they recommended that vehicles between 20,000 and 28,000-lb. gross-load restrict their speed to 15 m.p.h. If we go back still farther for a basis of comparison, we find a still more marked increase. The standard speed-rating for commercial vehicles which was given in the S.A.E. HANDBOOK dated September, 1918, gave a maximum speed of 16 m.p.h. for 1000-lb. trucks. For 5-ton trucks the recommended speed was 9 m.p.h. and for 10-ton trucks the recommended speed was 5 m.p.h. Today, 35 to 40 m.p.h. is considered proper for even the heaviest vehicles, while the lighter or so-called speed-trucks are expected to be capable of as high a speed as that at which most passenger-cars operate.

When we compare the engines in modern trucks with those of the earlier models, we find that the piston displacement has not increased appreciably for vehicles of the same rated capacities. Although gear ratios have been reduced to some extent, we cannot escape the conclusion that most of the increase in truck speed has been accomplished by running the engines faster. There was a time when 1000 r.p.m. was considered the proper speed at which to govern the engine in a 3½ or a 5-ton truck. Today, 1800 r.p.m. is considered a rather conservative speed for a six-cylinder truck-engine, while some operators object strenuously if the truck manufacturer suggests that they limit the engine speed to 2500 r.p.m.

The six-cylinder engine has played a large part in this trend toward faster trucks. Whether it was the cause or the effect is difficult to state. We are certain, however, that without the six-cylinder engine, present-day truck-speeds could have been attained only by means of greatly reduced gear-ratios, which would in turn have called for much larger engine per unit of load carried. The six has two distinct points of superiority over the four-cylinder engine, making it more adaptable to high-speed heavy-duty operation. One is its greater flexibility and wider range of power and the other is its comparative freedom from vibration.

Reasons for Six's Wider Power-Range

A number of reasons exist for a wider power-range of the six-cylinder engine. First, the six has a greater ratio of valve area to displacement than does a four of the same total displacement. This is because the bore and stroke are smaller for the six and that areas are proportional to the square of linear dimensions, while volumes are proportional to the cube. For the same reason

[1] M.S.A.E.—Assistant chief engineer, Continental Motors Corp., Detroit.

the ratio of bearing area to displacement is also greater for the six. This means that higher engine-speeds are both possible and permissible. The smaller bores permit the use of higher compression, which also makes for increased power per cubic inch.

Due to the greater number of suction strokes per revolution, a greater amount of mixture can be drawn in per minute through the same size of manifold. This results in increased volumetric efficiency and power. In the six, the angular spacing of the suction strokes of adjacent cylinders is 240 deg. The duration of the inlet-valve opening is generally about 20 deg. less than this, so that there is practically no possibility of cylinders with siamesed inlet ports robbing each other. In the four, this angular relationship is only 180 deg., so that an overlap of suction strokes of about 40 deg. occurs.

The principal reason for the comparative smoothness of the six-cylinder engine is the absence of secondary inertia forces which are present in all four-cylinder engines. These forces are due to the angularity of the connecting-rods, which causes greater acceleration and deceleration of the pistons near the top dead-center than near the bottom. This sets up an unbalanced force which tends to raise and lower the engine twice per revolution. Without going into a mathematical analysis, it can be stated that these forces are proportional to the weight of the reciprocating parts and to the square of the engine speed.

In the six-cylinder engine, although there is the same angularity of connecting-rod as in the four, the angular relationship of the cranks causes the secondary inertia forces to cancel out. The only unbalanced forces that remain are due to the sixth harmonic of the primary wave, and their magnitude is so small as to be hardly noticeable. From the foregoing it can be seen that the difference in power as well as the difference in smoothness of a four and a six-cylinder engine is not so marked when the displacement is small or the engine speed low. This explains why the small four used in passenger-cars and light trucks and the large but low-speed four used in tractors and industrial installations continue to hold their popularity. In the case of large-capacity trucks operating at high speed, which require both large displacement and high engine-speed, the advantages of the six-cylinder engine are more pronounced. It is to be admitted that these features, which give the six its superiority over the four, are in some respects disadvantageous in that they make it more subject to the abuse of overspeeding.

Fig. 1 shows the horsepower curve of a six-cylinder motor-truck engine of 420-cu. in. displacement, that of a four-cylinder engine of the same displacement, and that of the power required to propel a 4-ton truck on a level road. The third curve crosses the engine-power curves at 1860 r.p.m. in the case of the four and at 2460 r.p.m. in the case of the six. This indicates that the six-cylinder engine can and will be operated 32 per cent faster than the four unless means of restraint are employed. Also, the comparative smoothness of the six seems to create the impression that it is safe to operate it at much higher speed than does a four. This is permissible only to a limited extent and, since the restraining influence of vibration is lacking, it is essential that some other means be employed to limit the speed at a safe figure. It is certain that most of the troubles experienced with six-cylinder motor-truck engines can be traced to excessive speed.

Determination of Maximum Engine-Speed

In determining the maximum speed at which an engine should be operated, one of the most important considerations is that of bearing pressure. The bearing loads which must be taken into account in high-speed operation are not those caused by the explosion pressure, but are those due to the combined centrifugal and inertia forces. The centrifugal force is expressed by the formula:

$$F_c = 14.2 \cdot S \cdot W_{Rot} \cdot (N/1000)^2 \qquad (1)$$

where

S = stroke of the engine, in inches
W_{Rot} = weight of the rotating mass, in pounds
N = engine speed, in revolutions per minute

The inertia force is expressed by the formula:

$$F_i = 14.2 \cdot S \cdot W_{Rec} \cdot (N/1000)^2 \, [\cos\theta + (R/L)\cos 2\theta] \qquad (2)$$

where

W_{Rec} = weight of the reciprocating mass, in pounds
θ = crank angle, in degrees, measured from the dead-center position
R = one-half the stroke, in inches
L = center-to-center distance, in inches, between the upper and the lower connecting-rod bearings

In the case of the lower connecting-rod bearing, the combined load will be a maximum when the piston is at top dead-center. The inertia and the centrifugal forces will then both be acting in a vertical direction and their resultant will be their sum. My experience indicates that, for heavy-duty high-speed service, the maximum bearing-pressure should not exceed 1000 lb. per sq. in. at the horsepower peak.

Another important consideration so far as bearings are concerned is the amount of frictional energy or heat that must be dissipated per square inch of bearing surface. This can be expressed by the formula:

$$E_f = P \cdot C \cdot S \qquad (3)$$

where

E_f = frictional energy dissipated in the bearings, in foot-pounds per minute per square inch
P = mean bearing-pressure, in pounds per square inch

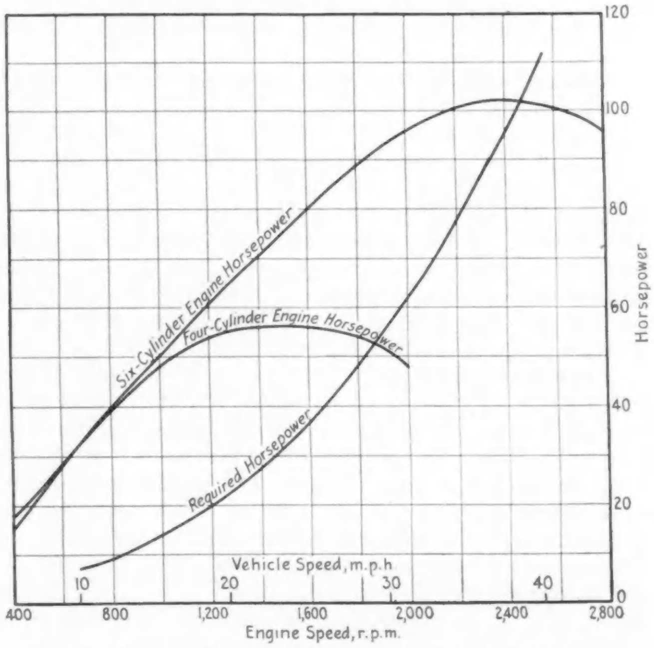


FIG. 1—POWER CURVES COMPARED WITH HORSEPOWER REQUIRED

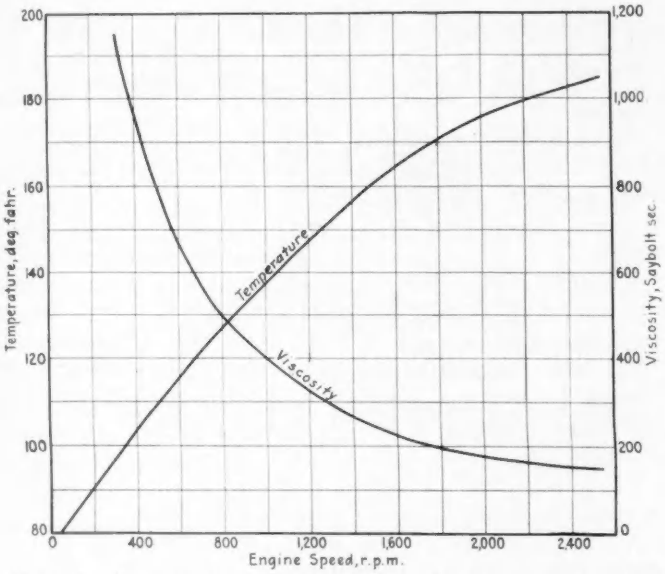


FIG. 2—CURVE OF CRANKCASE-OIL TEMPERATURE VERSUS ENGINE SPEED, AND VISCOSITY CURVE OF A HEAVY ENGINE-OIL VERSUS ENGINE SPEED

C = coefficient of friction
S = rubbing speed between journal and bearing in feet per minute

Since P is proportional to the square of engine speed and since S is proportional to the first power of engine speed, E_f will be proportional to its cube.

H. R. Ricardo uses a simplification of equation (3) which he calls the "bearing factor." This is the product of the bearing pressure in pounds per square inch and the rubbing speed in feet per second. My experience indicates that in high-speed heavy-duty service this factor should not exceed 30,000 at the horsepower peak.

It can be seen from the foregoing that, although bearing pressure can be reduced by increasing the bearing diameter, this would not reduce the bearing factor. To keep both bearing pressure and bearing factor at the proper figure, the bearing must have sufficient length. The principal consideration in determining bearing diameter is that of crankshaft stiffness.

Another important consideration in determining the maximum safe engine-speed is its effect on the temperature of the oil. My experience indicates that the temperature of the oil in the pan should not exceed 175 deg. fahr. The momentary temperature of the oil in the bearings and on the cylinder-walls will exceed this by a considerable amount.

Fig. 2 shows the temperature of the oil in the crankcase plotted against engine speed, and the viscosity of a heavy engine-oil plotted against engine speed. It can be seen that oil loses its viscosity very rapidly with increasing speed. When the viscosity drops below the critical point where the oil-film no longer separates the rubbing surfaces properly, undue wear will result.

Excessive oil-consumption is another undesirable result of too great a drop in viscosity, in turn caused by excessive speed. This is an evil in itself but should frequently be looked upon as a warning sign that, unless the engine speed is reduced, more serious troubles will follow.

Engine speed can be limited in a number of ways. The most obvious is by means of a governor. Another is by designing the engine so that it is incapable of running too fast. The most effective method is to use the proper gear-ratio. It must be borne in mind that vehicle speeds are in the end dictated by public demands and economic forces beyond the control of the truck engineer. If it is attempted to govern a truck at a speed which the operator considers too low, he will be very likely to render the governor inoperative and, when trouble results, the manufacturer will bear the ultimate brunt of it either in service expense or loss of sales.

The second method is a logical one and should be employed to a much greater extent. Very little reason exists for designing a large amount of power into a truck engine, principally for advertising purposes, and then demanding that the engine be governed at a speed far below that at which this high output is obtained. It is to be admitted, however, that this method of limiting engine speed must be employed with caution. If carried too far, the truck is likely to be seriously handicapped from a sales viewpoint.

To limit engine speed by the use of a small gear-ratio, one fundamental requirement must be met. The engine must be of adequate size. Insufficient piston displacement can be blamed for more cases of excessive engine-speed than can any other cause. When the engine is too small, one or both of two evils prevail. Either the gear ratio will be excessive or the truck will lack ability. In the latter case the truck will be unsalable as in the case of the underpowered engine. To overcome this, the manufacturer will increase the gear ratio so that excessive engine-speed will result in the end.

Engine-Size Determination Outlined

In determining the proper size of engine for a high-speed truck, two basic requirements must be met; first, that of performance, generally measured by accelerative ability, and, second, that of proper engine-speed. In other words, the engine must have sufficient displacement to develop the torque necessary for adequate acceleration, with a gear ratio that will produce the desired vehicle-speed without excessive engine-speed. This can be expressed by formulas giving the relationship between engine displacement and vehicle ability, and between engine speed and vehicle speed.

The resistance which any self-propelled vehicle must overcome consists of inertia, gravity and friction. Friction in turn consists of three elements; internal friction, rolling resistance and wind resistance. It can be shown that all of the foregoing factors except the wind resistance are approximately proportional to the load carried. Since most ability comparisons such as acceleration or hill-climbing tests are made at low speed, we can simplify matters by assuming that the total resistance to motion is proportional to the load moved. The resistance per pound will therefore be approximately the same for all vehicles under similar conditions. This unit resistance can be expressed as follows:

$$R = 0.031\,A + g + f \qquad (4)$$

where

A = acceleration of the vehicle, in feet per second per second
g = grade, in per cent
f = total frictional resistance per pound

If we know the maximum propelling-force available at the driving wheel per pound of load, we can derive a factor indicative of the comparative accelerative ability or hill-climbing ability by subtracting from it the unit frictional resistance. Formulas giving this maximum

propelling-force per pound of weight propelled have come to be the most commonly used indices of vehicle ability. These are generally known as the "ability coefficient" or "tractive factor" formulas. Assuming a maximum engine-torque of 0.64 lb-ft. per cu. in. of piston displacement, this can be expressed as follows:

$$T_f = (15.36\,V \cdot r)/(d \cdot W) \qquad (5)$$

where

T_f = tractive factor
V = piston displacement, in cubic inches
r = gear ratio
d = rolling diameter of the tires, in inches, generally taken as the nominal diameter
W = gross weight of the vehicle, in pounds

It is to be noted that equation (5) assumes an efficiency of 100 per cent between engine and axle. The reason for this assumption is the difficulty of separating internal friction from external rolling-resistance. A survey of practice shows that the value T_f for trucks varies between 0.057 and 0.100. This compares with 0.122 to 0.150 for passenger-cars. This seems somewhat illogical, for we know that acceleration and hill-climbing ability are just as desirable for trucks as for passenger-cars; in fact, trucks are expected to hold their own with any other type of vehicle on the road.

"Speed-Ratio" Factor Considered

As a means of comparing engine speeds in different vehicles, I use a factor which is called, for want of a better name, the "speed ratio." This factor expresses the ratio between engine speed in revolutions per minute and vehicle speed in miles per hour. It is equivalent to 1/60 of the number of engine revolutions per mile traveled. This factor must of course take into account both gear ratio and tire size. It is expressed by the following equation:

$$R_s = N/S = (336.13 \cdot r)/d \qquad (6)$$

where

R_s = speed ratio
N = engine speed, in revolutions per minute
S = vehicle speed, in miles per hour
r = gear ratio, as for equation (5)
d = tire diameter, as for equation (5)

The values of R_s for six-cylinder trucks range between 48 and 72, while for passenger-cars this factor is between 40 and 60. Here again apparently no good reason exists why truck practice should differ greatly from that for passenger-cars. A great many trucks are traveling at least as fast as, and in many cases faster than, the average passenger-car; in addition, the speed is generally much more sustained. For high-speed long-distance hauling the speed ratio should surely not be greater than the maximum passenger-car figure of 60. Further, it has been my observation that whenever this figure exceeds 50, the engine speed should be controlled by a governor. Below this figure, the use of a governor is not so imperative, as the engine speed will be limited by the speed of traffic in general to a point that should not be excessive.

"Load Factor" Analyzed

The simplest and most readily determined index of the duty imposed on the engine is the ratio of the total load carried to piston displacement, which I shall call the "load factor." A survey of practice shows its values to range between 30 and 48 lb. per cu. in. for high-speed six-cylinder trucks, considering capacity load only. In the case of truck-tractors drawing trains of trailers, I have encountered many cases where this factor is as high as 175 lb. per cu. in. This compares with 13 to 22 lb. per cu. in. for passenger-cars carrying the rated number of persons.

By combining equations (5) and (6), we can derive an equation expressing the load factor in terms of speed-ratio and tractive factor, as follows:

$$F_1 = W/V \doteq (0.0457 \cdot R_s)/T_f \qquad (7)$$

where

F_1 = load factor
W = gross weight of the vehicle, in pounds
V = piston displacement, in cubic inches
R_s = speed ratio
T_f = tractive factor

Thus, since the load factor is directly proportional to the speed ratio and indirectly proportional to the tractive factor, equation (7) is merely another way of stating that too small an engine will result either in excessive engine-speed, insufficient ability, or both.

As an example of the relationship between these three factors, we will substitute in equation (7) values of R_s and T_f which we know to be representative of good practice. This gives:

$$F_1 = (0.0457 \cdot 60)/0.075 = 36.5 \text{ lb. per cu. in.} \qquad (8)$$

If we increase the load factor to 48, which is about the highest value found in practice, we will have either a 31 per cent drop in ability or increase in engine speed. This would give us an ability coefficient of 0.057, which is rather low, or a speed ratio of 79, which is too high.

Reasons for Comparisons Stated

My main reason for making so many comparisons with passenger-car practice was to show how much more the operator is asking from the engine in his truck than he asks from the engine in his car. This is in spite of the fact that he must operate his truck many more miles per year, and that profitable operation demands much longer life and a much higher degree of reliability. Interruptions of service due to mechanical troubles cannot be tolerated, and the mileage period between overhauls must be extended far beyond that considered satisfactory for a passenger-car. The engine manufacturers frequently complain because truck builders and operators abuse the engines, but in many cases they are the ones who are at fault for not clearly defining just what can reasonably be expected from them. It is for this purpose that the foregoing factors are offered. It is not possible to lay down hard and fast rules for relationship of engine size to load carried. It is hoped that these formulas and factors will provide a means by which an operator can measure the duty imposed upon the engine and can compare this with the limitations of the engine.

Efforts To Meet Operating Demands

Now that I have told you how hard the operators are working our engines, no doubt you will be interested to learn what we are doing to have our engines meet the conditions of service. I have frequently been asked the question, "Just what constitutes a good truck-engine and wherein does it differ from a good passenger-car engine"? In the design of a heavy-duty six-cylinder motor-truck engine, ruggedness and reliability must come before all other considerations. Lightness is a desirable feature in any automotive vehicle, and low cost is always of prime importance from a competitive viewpoint. However, these must be subordinated in

the interest of durability. A good flat torque holding up well between 600 and 1800 r.p.m. is of much more importance than high peak-power. In fact, any truck engine should be to a certain extent self-governing and should not peak at too high a speed for this reason. Accessibility is very important, so that repairs and adjustments can be quickly and easily made.

Due to the continuous nature of truck operation, bearing surfaces should be proportionately greater than in a passenger-car engine of similar size. A large amount of oil should be circulated, not only for lubrication but also for the dissipation of frictional heat. In this regard it must be noted that high oil-economy can be and frequently is poor economy, for, when it is carried too far, it is bound to result in excessive wear. To assure satisfactory cooling for long periods of full-load operation, a large amount of water must be circulated at all speeds and water passages must be of ample capacity. These passages should completely surround all cylinders and valves and should extend well below the top of the piston when it is in its lowest position. Only the best materials are good enough for this type of engine. The cylinder iron must be as hard as it can be made and still be machinable. The addition of nickel and chromium has been found to add considerably both to wear resistance and strength of the cylinders. Crankshafts should be forged from alloy steel to produce both strength and hardness.

Heavy-Duty-Engine Construction Shown

Fig. 3 shows our Model 20R engine developed especially for heavy-duty service. The crankshaft and the bearing construction should be noted in the sectional views. Seven main bearings of ample size are incorporated. The bearing-cap design is very rigid and effectively prevents the bearing shells from loosening and permitting pounding out.

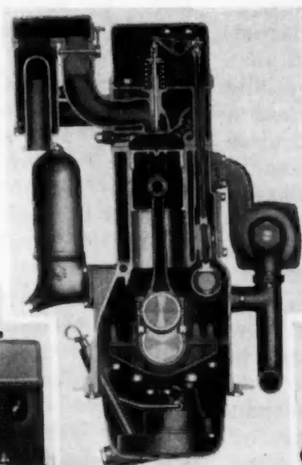
The overhead-valve construction for this type of service has many advantages. By removing all ports from cylinder-block, the distortion due to expansion and contraction is reduced and the cylinder-barrels stay round. Therefore, it is possible to fit pistons more closely than is ordinarily done in engines of this size. This construction has also eliminated trouble from cracked cylinders and valve seats, which has been a very serious matter in high-speed heavy-duty service. This design also affords good accessibility. Valves can be easily reached and adjustments quickly made. Fleet owners are especially favorable to this design as it enables them to keep a spare cylinder-head on hand and, when valves need grinding, the old head can be removed, the new one installed and the grinding done on the bench while the truck goes on about its work.

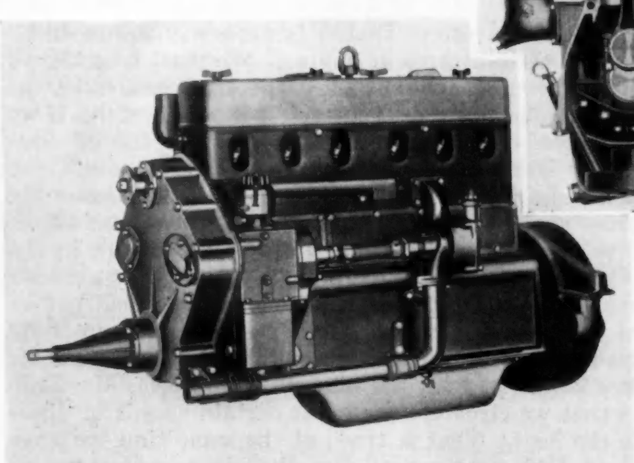
The oil-pump is unusually large and the oil is fed by pressure to all wearing points of the engine, including rockers, accessory shaft, fan bearing and timing chain. On its way to these points, the oil is passed through a large-capacity filter. The front-end drive is by means of a silent chain, 2¼ in. wide, and is of the heavy-duty type made entirely of alloy steel. An automatic idler which keeps the chain always at a constant tension is incorporated.

Manifold and Other Construction

The manifold construction is one which has been found particularly adaptable to this type of engine. Due to the wide extremes of service which have to be met, it is not possible to have a condition of temperature that will suit all of them. For this reason the intake and the exhaust manifolds are kept separate and the heat is circulated through the heater box of the inlet pipe by means of an adjustable valve. For long-distance high-speed hauling, this valve is kept in its coolest position and, because the intake and the exhaust are separated, very little heat can pass over by means of conduction. When the other extreme of service is met where the speed is low and the stops are frequent, additional heat is thrown into the intake pipe.

The water-pump is unusually large and has an output of 80 gal. per min. at 2000 r.p.m. Water-jackets extend the entire length of the cylinder-barrels, and the ports and valve seats are completely surrounded by water. The water from the pump enters the upper part of the cylinder-block so that the water in the barrels is not circulated. This makes for





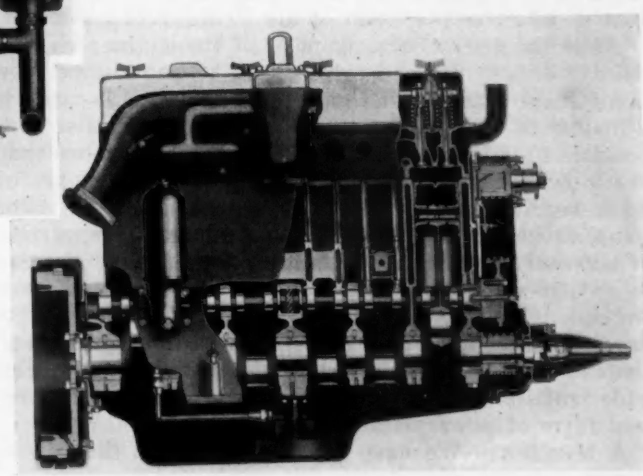


FIG. 3—MODEL 20-R CONTINENTAL MOTOR-TRUCK ENGINE
An Exterior View of the Left-Hand Side Is Shown at the Left. At the Lower Right Is a Longitudinal Sectional View. A Cross-Sectional View Is Shown at the Top

quick warming-up and helps to prevent dilution. The passages between cylinder and head are located so that a large amount of the water passes over the spark-plug bosses and the valve seats.

The arrangement of accessories is always a problem in the design of a truck engine. The engine shown in Fig. 3 has provision for generators up to 600-watt capacity, for an air compressor, a magneto, a distributor, or both, and for an air-cleaner and an oil purifier. Starting-motor pads are installed on both sides of the engine; this has been found to be a very desirable feature, especially for export trucks. Nothing has been spared to make this engine equal to its task. The design shown is not the cheapest possible, but the results experienced have proved that the extra cost of the numerous refinements of design has been money well spent.

THE DISCUSSION

CHAIRMAN J. F. WINCHESTER[2]:—This session results from an effort on the part of the committee to have the designing engineers and the operators meet each other. Some of the Society members have felt that true cooperation between these two groups has been neglected to some degree, and the idea is to promote greater harmony within the Society. I hope many of the problems that you are trying to solve will be discussed, and that the discussion will enlighten you satisfactorily.

Oil-Cooling Problems Analyzed

A. W. SCARRATT[3]:—Mr. Kalb's description of a first-class engine for motor-truck service seems to me to bear out our own experience fairly well. He mentioned the desirability of holding the lubricating-oil temperature under maximum operating-conditions to from 175 to 180 deg. fahr. When trucks must work in atmospheric temperatures as high as 125 deg. fahr. and run for as much as 40 hr. continuously with scarcely a let-up, how can we hold to this temperature? He referred to the life of the front-end drive as being approximately 100,000 miles. That is possible, provided other things are exceptionally well done. One of them is to keep dirt out of the engine. We find that with front-end chain-drives the chain wear and adjustment are generally a barometer of how much dirt is getting into an engine.

The use of engines in heavy-duty trucks, especially in contractors' service, has brought about as great a need for careful consideration of air-cleaning devices on the breathers and on the carbureter system as in tractor work. Unfortunately, we have not space enough under the hood of the truck to install the type of air-cleaning system that is generally used on a tractor; but just as effective a system of air cleaning is needed.

As to the general arrangement of the engine, whether it shall be an overhead-valve or an L-head engine, how many main bearings it shoud have and the like, that is a matter of engineering judgment. We feel that it is possible to build good six-cylinder engines in more than one general layout, but our personal preference is for seven-bearing crankshafts and overhead valves. The complication of an engine, because of the large variety of accessory requirements, is a matter of much concern to anyone developing heavy-duty truck or motor-coach engines. We cater to an international trade and so have the right-hand and the left-hand-drive varieties to contend with. To satisfy all the demands of a world-wide trade is not an easy thing to do with a standardized form of powerplant.

A MEMBER:—We have been using fins in the pan to cool the oil and also aluminum instead of cast-iron pans. With a large volume of oil in the pan we were able to keep the temperature down to 10 or 15 deg. less than the water temperature. An oil cooler of the type one must use to take care of this does not give as good satisfaction as does a fin pan.

Dual and double ignition have not been mentioned. The Fire Underwriters now rule that engines installed on fire apparatus must have double ignition; that is, two spark-plugs. A number of different truck manufacturers sell their trucks for light-weight fire-apparatus. I fail to see how any of us are going to get any business unless the Society finds out why the Underwriters require two spark-plugs instead of dual ignition, with which one can use a magneto and a generator with a battery system which, with a switch, will operate the same set of plugs. I do not see why it is necessary to have two sets of spark-plugs.

Special Means of Oil Cooling

A. H. FROST[4]:—Oil cooling is a problem of special interest. About eight years ago I designed an oil cooler for a marine engine. The cooler used a very thin oil-film. By passing water on both sides of the film, we found the cooling very effective and, with the low temperature of the water that we had from the lake, we could reduce and hold the oil temperature from 230 deg. fahr. to 120 deg. fahr. Using a thin film makes this possible. If a stream of oil flows through a 1-in. pipe and the temperature is very low on the outside, only the skin surface of the oil is cooled and the center of the oil goes through hot, so that cooling area must be increased. Therefore, we cool both sides of a thin oil-film.

The paper mentions that it is necessary to use an oil cooler on certain types of engine. We must keep the oil temperature far enough below the temperature of the bearing metal to prevent softening it. Therefore, if we have types of engine in service in which the oil temperature is likely to approach that dangerous condition, it is necessary to install a cooler; but, in other cases the engines are running cool enough and, when I am asked, I have always answered that if the temperature in the crankcase is near enough to the danger point a cooler should be used. Otherwise, *an oil cooler should not be used.* The particular design that would fit a given truck engine or automobile engine would have to be developed.

In connection with the oil-cooling problem, Mr. Kalb says that we circulate the oil at certain speeds to dissipate the heat. That is true; at the same time we have to hold that precious oil-film that is so necessary to prevent engine wear. Mr. Scarratt mentioned the amount of dirt that passes into the oil-film. I have a sample that was taken from an oil-filter which shows the abrasives that were in circulation in the oil; par-

[2] M.S.A.E.—Superintendent of motor-vehicles, Standard Oil Co. of New Jersey, Newark.

[3] M.S.A.E.—Chief engineer, motor-trucks and motorcoaches, International Harvester Co., Chicago.

[4] M.S.A.E.—Technical adviser to Detroit sales division, Vacuum Oil Co., Detroit.

ticles of metal, bronze, steel and cast iron, even though a fine-mesh strainer was attached to the suction of the pump.

Torque Comparisons Made

ARTHUR J. SCAIFE[5]:—Mr. Kalb compared a four and a six-cylinder engine of the same cubic-inch displacement. What would be the comparable torque curve under the same conditions? The thing I am interested in is that we talk horsepower up to maximum speeds of 2800 and 3000 r.p.m. and then install a governor to limit its speed to 1800 or 2100 r.p.m.; then, when we want to find out what the ability of this particular engine is, we ask "What is the torque?" We talk horsepower and figure torque.

L. P. KALB:—The two engines have practically the same amount of torque per cubic inch. The six-cylinder engine has its maximum torque at about 1000 r.p.m., and the four-cylinder engine has its maximum at about 875 r.p.m. But the six-cylinder-engine torque holds up longer, at both lower speeds and at higher speeds, than does that of the four-cylinder engine. It is natural to assume that, with greater horsepower, the torque curve will hold up higher at the high speeds. My reason for comparing the four and the six-cylinder engine was not to make a case for the six, but rather to show its high speed-capabilities and the necessity for limiting the speed.

THOMAS S. KEMBLE[6]:—I heard Mr. Kalb present a paper some time ago in which he asked for specific limitations of the engine speed and, while he was asking the trade to hold down the speed of an engine which he was furnishing, he was working along the lines of obtaining higher speed for those engines so that he would not need to hold the limitations so low. He still wants limitations, and that is right.

Higher Speed Reduces Traffic Impedance

Regarding the speeds of trucks on the road, perhaps the greatest objection that the public has to the great use of trucks on the highways, aside from damage to the roads, which is a decreasing objection because trucks are being built so they do not damage the roads so much, is the impedance of traffic by the trucks. Perhaps the greatest asset we have had in reducing this objection is the greater speed of the trucks. Most of them run now at speeds that offer very little impedance to passenger-car traffic. It will be a mistake to reduce this top speed too much unless it is absolutely necessary. The average speed of the truck affects the speed of other traffic on the highways. The accelerating ability and the hill-climbing ability of the truck affect the daily mileage of the truck itself. So, these must not be reduced; they must be increased, if possible.

I believe that the greatest difficulty with the high-speed operation of the engine is only indirectly engine temperatures; it is directly oil viscosity, and the oil viscosity of course is affected directly by the temperature of the oil. So, probably, the biggest and simplest thing that we can do to make the higher engine speeds with all their accompanying advantages more practicable, is to maintain a lower oil-temperature through some oil-temperature regulating-device.

It is not simply a matter of cooling the oil; it is a matter of regulating the oil temperature. When someone gives us a simple, rather inexpensive device—which I believe can be done without too much development work—which will hold the oil temperature within some small range, a tremendous part of the difficulties that have been troubling us for years and are still troubling us will fade out of the picture.

F. C. MCMANUS[7]:—Since the four and the six-cylinder engines had the same displacement, I think Mr. Kalb should have shown a fuel-economy curve.

Regarding oil cooling, we used an auxiliary system on our engines for a long time. A container, an integral part of the cylinder-block, was cast right next to the water-jacket. This was about the best temperature regulator of which I know. It was sufficiently close to the water-jacket to make it hold the oil temperature to about 180 deg. fahr. I believe another company recently built a truck engine which was equipped with an oil-cooling system.

Change of Crankcase Oil Still Needed

CHAIRMAN WINCHESTER:—On the subject of oil regulation, we sometimes see steps taken or means used that perhaps do not check with experiments that have been made. I refer to the frequent changing of oil in crankcases. Mr. Frost mentioned the large amount of accumulation of foreign matter found in oil filters. Undoubtedly, oil filters are a great help, but the engine designer wants to have the maximum perfection for the engine and, to my mind, even though oil filters and air filters are installed, there is still need for frequent changes of lubricating oil. The amount of protection that this gives an operator and the engineers is very considerable, and I think that, from our experience in analyzing different types of oil that are now coming out of crankcases, the reputable manufacturers will, as time goes on, recommend changes more frequently than once in every 2500 to 3000 miles. They find that, in the long run, the additional devices that have been installed are not functioning in exactly the way they should, and that the small difference in cost of operating vehicles with more frequent changes of oil will be well repaid eventually.

Mr. McManus mentions the type of oil well which his company installed on the side of the engine cylinder. My experience with that particular type of device was very satisfactory. I believe it did a great deal of good and yet, in his company, we find a new school; we find that this device has been taken off, and that the oil temperature is no longer regulated. I am frank to say that, without the regulation, we are having more trouble than we did when we had plenty of regulation.

[5] M.S.A.E.—Consulting field engineer, White Motor Co., Cleveland.

[6] M.S.A.E.—Consulting engineer, St. Louis.

[7] Jun.S.A.E.—Engineering department, International Motor Co., New York City.

Cold Carburetion

Discussion of Carl H. Kindl's Annual Meeting Paper[1]

THE DISCUSSION relates mainly to whether the gain in power and speed or the better cold-starting of the engine through use of the cold-carburetion system is more advantageous; the effect on distribution of the mixture caused by drop in air velocity at the valve ports; increase in compression-ratio; crankcase-oil dilution; loading effect after continued idling; the possible reason for reduction of detonation tendency; whether different grades of fuel cause a difference in acceleration; how spark-advance compares with that used with conventional carbureting systems; whether cold carburetion has an advantage in starting cold on fuels of low volatility; saving of weight and cost over heated carbureting systems; the possibility of application to aircraft engines; amount of vaporization of the fuel in the primary tubes; possible fuel economy; lack of knowledge of the pneumatics of flow through unsymmetrical shapes; and the possibility of improving distribution by using the light gasoline-fractions that are commercially available in large quantities but cannot be used with present heated carbureting systems.

CHAIRMAN F. C. MOCK[2]:—I hesitate to ask Mr. Kindl for specific reports of the power and speed obtained with this system as compared with current equipments, but would like to know which, in his estimation, is more advantageous, the gain in power and speed that he gets or the better winter performance. I have had demonstrating evidence of this last and know that the warming-up period is very short. It does not pay a manufacturer to put on his car anything that his sales and advertising departments cannot persuade the public it wants; so I should like to have Mr. Kindl's expression of how this has appealed, as regards increased power and cold-weather operation, not only to the engineers to whom he has shown it, but to the user or car purchaser.

THOMAS J. LITLE[3]:—With a given overhead-valve engine, what increase in power is possible with full coverage?

ALEX TAUB[4]:—What happens to distribution after the mixture gets out of the cold manifold and into the ports? We know that, with mixture treated the best way we know how, 50 per cent of our troubles are still left at the ports. The added difficulty with this system is that the velocity of the air-fuel stream through the small manifold is high up to the time it reaches the ports, where it strikes a big area and therefore a drop in velocity follows. Handling liquid under those conditions is a rather difficult problem, even for an overhead-valve engine.

R. W. A. BREWER[5]:—Is there any fundamental difference between this method and the very early methods that were adopted on internal-combustion engines, as, for example, the one in the Cadillac single-cylinder engine of about 25 years ago? The fuel was pumped directly into the valve pockets. Also, a number of Antoinette engines were made 20 years or more ago in which the fuel was pumped directly to the valve pockets, and these engines were successfully made and flown. They were of the eight-cylinder V type.

HAROLD CAMINEZ[6]:—How does the use of cold carburetion make possible an increase in compression ratio with no higher compression when the mixture is cold than with ordinary-mixture carburetion?

A MEMBER:—How is crankcase-oil dilution affected by this method of carburetion?

CHAIRMAN MOCK:—Will Mr. Kindl answer a few of these questions now?

Cold Starting Appeals to Car Owners

CARL H. KINDL:—Regarding the relative advantages of the increase in power and the better cold-weather performance, I will say that, from the viewpoint of the car manufacturer and the designing engineer, the increase in power seems to be the more important factor. Cold carburetion is a very cheap way of getting extra power out of the engine; in other words, it is not necessary to put any more material into it, and that is what the car manufacturer is primarily interested in. But we find, through the application on private cars, that the point that has the greatest value to the owner is the easier cold-starting and driving away in winter. If it did not give as much power, the owners would like it anyway on account of the cold drive-away advantage that it gives.

The percentage of increase in power varies with the design of the engine. From such experience as we have had, the power increase, taking advantage of the increase in compression that is possible with the same detonation tendency, will vary from 7 to 13 per cent. It is virtually uniform throughout the entire range of operating speed. This increase in power varies somewhat, depending on how well the conventional carbureter application is made. Some improvement might be made with the hot manifold.

Some Fuel-Air Mixing Occurs at Ports

Regarding the distribution of liquid in the ports, we do not know a great deal about it except that we have very little trouble there. If the liquid passes through the valve ports in the right amount, it seems to divide

[1] Published in the S.A.E. JOURNAL, February, 1930, p. 159. The author is chief engineer of the Delco Products Corp., of Dayton, Ohio, and is a Member of the Society. The abstract accompanying the paper is not reprinted herewith but a summary of the main trend of the accompanying discussion is given.

[2] M.S.A.E.—Engineer, Bendix Aviation Corp., South Bend, Ind.

[3] M.S.A.E.—Director of engineering, Holley Carburetor Co., Detroit.

[4] M.S.A.E.—Development engineer, Chevrolet Motor Co., Detroit.

[5] M.S.A.E.—Consulting engineer, Aircraft Engine & Accessory Development Corp., Jenkintown, Pa.

[6] M.S.A.E.—Engineer in charge, aircraft-engine division, Cadillac Motor Car Co., Detroit.

properly in a siamese port, except for the fact, as I mentioned, that some effect is produced by the firing-order time-intervals on the suction strokes.

The suggestion has been made that the most desirable form of construction would be individual valve-ports for each cylinder. This undoubtedly would produce the optimum distribution. Some work was done along this line, but such good results were obtained with the siamese ports and it was so easy to make an application to cylinder-heads without any change that we worked on the siamese port.

I am not familiar with the particular application on the Cadillac eight-cylinder V-engine, but considerable work has been done in the General Motors Corp. Research Laboratories on mechanical distribution of fuel to the engine. There seems to be some limit as to how far one can go in delivering liquid fuel to the engine. Just how much mixing with air is necessary before it enters the combustion-chamber I cannot say definitely; some tests indicated that we could not deliver the fuel as a liquid directly into the combustion-chamber without having some undesirable results. In our work the fuel is delivered right at the valve port and some mixing occurs; just how much we do not know. The exact location of the point where the fuel is delivered seems to make very little difference, but we have not extended our tests sufficiently to find out just how definite this is.

CARL H. KINDL

Regarding the reasons for increase in compression, I cannot say directly why this factor enters. We know that more weight of air goes into the engine, and from that fact I think detonation might increase, but actually it always decreases. Some of the fundamental equations on engine power that have been given before the Society involve temperature and detonation, and I am sure that such data can be found in the files of THE JOURNAL.

The last question was concerning crankcase-oil dilution. From early tests made with the device, the dilution seems to be less, the chief reason being that, as soon as the cold engine is started, inherently good distribution is obtained, and, although the use of the choke in extremely cold weather is desirable, all the cylinders receive a rich charge, so that virtually all will fire; whereas, with the conventional system, a few cylinders may get half the charge, which may be so rich that those cylinders will not fire and liquid fuel will pass the piston.

CHAIRMAN MOCK:—In partial answer to Mr. Brewer's question, one fundamental and important difference between this and the Antoinette system, I believe, is that the latter had a fuel-pump that had no connection with the air-flow; if the throttle was closed to cut off the air, the pump did not know it and was likely to keep on feeding the same amount of fuel; in particular, if the throttle was kept in one position and the engine speed allowed to change, the pump did not change the fuel-flow as the air-flow changed.

A Second Group of Questions

PROF. H. M. JACKLIN[7]:—After long-continued idling with cold carburetion, may not the mixture in the port be a rather rich one, with the result that a loading effect occurs?

MR. LÍTLE:—In the work that was done with the glass manifold, was a progressive precipitation dropping out of fuel down the tube noticed, and if so, would it not be advantageous to make those tubes as short and direct as possible?

E. E. DEAN[8]:—I believe the paper stated or inferred that no attempt was made to obtain atomization. It would seem to follow that the object sought was merely to deliver the correct amount of fuel and air required. The resulting charge may get some degree of mixing around and beyond the inlet-valve port, probably resulting in a stratified charge in the cylinders. Might not this lack of homogeneity of charge result in a slow-burning mixture and account for the absence of detonation?

M. R. WOLFARD[9]:—What grade of gasoline was used when determining the amount of increase in power? I think that the grade of gasoline would have a very definite bearing on this increase.

J. C. STRAUB[10]:—What effect do different grades of fuel have on calibration of the jets in the carbureter?

HARRY F. HUF[11]:—Is there any indication of a difference in acceleration when using aviation fuel and normal motor gasoline, such as has been shown by recent papers on the subject of acceleration?

T. S. KEMBLE[12]:—In connection with the question regarding whether this involves a slow-burning fuel, I suggest that if Mr. Kindl has records of the optimum spark-advance under the different conditions they will indicate the correct answer.

No Loading After Long Idling

MR. KINDL:—Professor Jacklin asked about the loading of the manifold following idling for long periods of time. We have such trouble with L-head engines, caused by the fuel loading in the valve port, but with the valve-in-head engine no such condition exists; in fact, our manifolds usually are made with a slight downward inclination to the ports so that there is no place for fuel to pocket and it actually runs into the valve port, where we have had no particular difficulty. The valve ports seem warm enough to prevent any quantity of fuel gathering there.

Shortening the length of the primary tubes seemed to give some advantage, except that, as suggested by Mr. Lítle, when the fuel was delivered to the main air-stream, the velocity immediately decreased and we had the same kind of troubles that occur with conventional carbureters when heat is not applied. Also, loading would occur; the fuel would puddle in the cold parts of the manifold and at low speeds the air velocity would not be sufficiently high to move it.

From work done with a Neon-tube stroboscope, the fuel delivery from the primary tube actually seemed to

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[9] M.S.A.E.—Engineer in charge of research laboratory, Hopewell Bros., Cambridge, Mass.

[10] M.S.A.E.—Assistant engineer, motor-truck division, International Harvester Co., Chicago.

[11] Jun. S.A.E.—Senior engineer, in charge of automotive laboratory, Atlantic Refining Co., Philadelphia.

[12] M.S.A.E.—Consulting engineer, St. Louis.

cut right off sharp when the inlet valve closed. The tube may have contained some vaporized fuel that could not be seen with the eye, but when the valve closed the discharge into the main airstream immediately stopped; in fact, we know that the airstream actually reverses for an instant when the valve closes and small particles go in the other direction.

Mr. Dean suggested that the improvement in detonation probably was caused by stratification of the mixture, which would affect its burning. Undoubtedly some such condition exists, but we have made no attempt to find out just why.

Effect of Different Grades of Gasoline

Only conventional grades of gasoline were used in making the power comparisons. However, in working with accelerations in warm weather in the summer, one may easily be misled because almost anything works on a hot day; so we used a mixture of about 50 per cent kerosene and 50 per cent conventional gasoline. The kerosene cut down whatever vaporization there might be and also, because of its greater viscosity, actually gave a leaner mixture. This mixture was used merely to exaggerate the deficiencies of the system so that they would be easier to pick out for improvement.

The effect of different grades of fuel on calibration would be no different with this type of carbureter than with any other. The grades of fuel might affect it through their difference in viscosity, but that is as true of any conventional carburetion system as it is in this case.

MR. KEMBLE:—Do you have to use the same spark advance with this manifold that you would use under the same set of conditions in the same engine with the conventional carbureter manifold?

MR. KINDL:—Ordinarily, if the compression is not changed, the spark advance is increased sometimes about 5 to 7 deg. to get about the same amount of detonation.

MR. KEMBLE:—Do you have to increase the spark advance for maximum power, or do you get the maximum spark advance, maximum power and detonation altogether?

F. C. MOCK

MR. KINDL:—That all depends upon whether the compression is raised. If direct comparison is made with this carbureter and another, ordinarily the spark is adjusted for the best position with either outfit. In most of our test work, however, the spark is left alone, although the practice seems to vary with different companies. Some companies always adjust the spark on making a power run, while other companies desire to keep the standard setting of their regular equipment when making tests of the system.

C. H. TAYLOR[13]:—In your stroboscopic investigation at closed throttle, do you get that same cutting off, reversal of flow and no flow during the time the valve is closed? I understand perfectly your statement with respect to open throttle, but it seems to me that, under closed throttle, when there is considerable depression in the manifold, the flow should be continuous through each of the fuel branches.

MR. KINDL:—The effect of shutting off delivery of fuel from the tube did not seem to be quite as effective with part throttle, although the carbureter that was used at that time under part-throttle conditions, up to say 40 m.p.h., ran entirely on the primary manifold, and the fuel was vaporized considerably at part throttle; so the entire picture was not definite and clear as to when the tube delivered fuel or when it cut off; therefore the conclusion is not quite so positive regarding the effect at part throttle.

R. W. A. BREWER

I might say that, with equal pulsation intervals or suction strokes, the distribution is 100-per cent perfect; hence, if a crankshaft could be designed to have inherent balance and at the same time give us equally timed pulsations from all the cylinders, some of our problems would be entirely eliminated.

MR. BREWER:—I doubt whether the point I made was caught. What I was trying to get at was the state of the mixture as it enters the cylinder. If the fuel were admitted as a saturated vapor or as a liquid spray, would it have a tendency to burn slowly or rapidly and how would that tendency affect the economy as plotted against any particular power output?

MR. KINDL:—We cannot state definitely for we do not know about any difference in the burning of the fuel with this type of carburetion, although, aside from the change in detonation, no difference is evident. We found some instances in which an engine that might be called sensitive missed under certain conditions, mostly part-throttle conditions, and upon applying the cold carburetion we never found any indication that this condition was worse. In some cases we had trouble owing to distribution and things that were later corrected, but, as far as fundamentals are concerned, we never have been able to blame any peculiar action of the engine on the admission of liquid fuel to the valve ports.

Liquid Fuel Vaporized in Cylinder

NEIL MACCOULL[14]:—The idea seems to be prevalent that, when using cold distribution, in which the fuel is not vaporized until it gets to the ports, liquid fuel must be present in the cylinder during the compression and firing strokes. The fact may possibly be overlooked that the inlet valve has sufficient heat to do considerable vaporizing, as has also the very hot residual gas that is in the cylinder when the valve opens. We have some evidence from several types of experiment that almost any gasoline entering the cylinder port as a liquid will be well vaporized before the beginning of the compression stroke. This, of course, affects the question of crankcase-oil dilution. Many times I have heard the belief expressed that a carbureter system giving a perfectly dry mixture

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[14] M.S.A.E.—Automotive engineer, The Texas Co., New York City.

should greatly reduce dilution in the crankcase. Several years ago we heated the air going into the carbureter of a four-cylinder engine. We eliminated hot-spots during this experimental work and varied the temperature of the air going to the carbureter over a range from 32 to 300 deg. fahr. Such a temperature range would cover mixtures from those which are very wet to those almost entirely dry. At various steps along this range we took very careful measurements of crankcase-oil dilution under controlled conditions developed for the occasion, and we found that the carbureter-air temperature made virtually no difference in the amount of dilution. That seemed to be rather good evidence that the gasoline which got into the crankcase oil must have passed the pistons in a state of solution in the lubricating film on the cylinder-walls, and the quantity of gasoline that got into the oil film on the cylinder-wall was got by absorption from the gasoline vapor.

As for detonation, I do not see that anything unexpected results. We all know that any increase of the temperature of the charge in the cylinder will make it detonate more readily, and, conversely, anything that will keep it cooler will tend to retard detonation.

Trouble Encountered with L-Head Engine

MR. TAYLOR:—How did the performance of the L-head engine that you worked with actually compare, Mr. Kindl, with our present carburetion system? Did you succeed in making a very positive improvement in the L-head engine?

MR. KINDL:—The only difference in the operation of the L-head as compared with the valve-in-head engine was the trouble caused by loading which existed at wide-open throttle in the neighborhood of 10 m.p.h. and below. Then it was only a transient condition; for example, upon accelerating from 5 m.p.h., the fuel would begin puddling in the valve pocket and the engine system would run lean until a certain amount of fuel collected, after which operation became normal. Then, if the speed was increased up to say 20 m.p.h., this additional fuel which was puddled in the valve pocket would enter the combustion-chamber and run rich for a few revolutions. Otherwise, there is no difference. Some devices were used to overcome this one inherent difficulty, but we did not have much faith in them or think they were as good as they might be, and, since the problem did not exist with the valve-in-head engine, we somewhat arbitrarily decided to put all our efforts on the more desirable engine.

NEIL MACCOULL

J. MILTON DAVIES[15]:—Has this system any advantages as far as starting cold on fuels of low volatility is concerned?

MR. KINDL:—I cannot correctly answer that question. There may be some advantage, but I do not know how much. With this device there is no question that fuel can be delivered to the cylinder at very low cranking speed. Because of the small size of the primary tubes, which alone are used when cranking, the velocity is considerably greater than with the conventional manifold, but just how far this gain would extend with low-volatility fuel I really do not know.

W. E. ENGLAND[16]:—Has this system been developed to the stage that it is ready to be placed on the market, or when will it be?

The illustrations indicate that there is evidently a considerable saving in weight and therefore in the cost of this equipment. Can you tell approximately what percentage in saving is made on this system as applied to a particular engine?

MR. KINDL:—I have no definite figures. I believe that the actual weight with this system is less than with the conventional heat-trap mechanism and heat risers, although the carbureter itself, with the addition of the automatic valve and the three jets, is perhaps a little more expensive than the conventional carbureter. We feel, however, that there is an over-all saving with the cold carbureter.

Application of System to Aircraft Engines

MR. CAMINEZ:—Has this cold carburetion been applied at all to aircraft engines and, if so, has it shown any improvement?

CHAIRMAN MOCK:—I do not know of any such applications. I should be rather interested to see them. The chief reason for heating the charge on aircraft engines is to prevent freezing, with the fuel we now use. That is to say, if a pilot starts out on a day when the atmosphere is saturated with water at a temperature of about 40 deg. fahr., with a carbureter to which no heat is applied, ice will form around the jet wherever any considerable vaporization of fuel occurs. That is the most serious condition we are fighting today and, so far as we know, we must apply heat to avoid such trouble.

MR. CAMINEZ:—Does this system evaporate the fuel?

CHAIRMAN MOCK:—Some evaporation occurs in the tubes. The mixture ratio in the tubes is presumably around 4 parts of air to 1 of gasoline.

A MEMBER:—Have any economy runs been made with the cold-carburetion system?

MR. KINDL:—The economy has always been carefully watched, both on the dynamometer and on road tests, measuring the fuel used and making gas analyses, and no improvement has been observed over properly carbureted conventional jobs with the right amount of heat supplied. When the conventional heated carbureter is properly applied, it is virtually impossible to do any more from the standpoint of economy, if each cylinder is getting its proper mixture and the carbureter is calibrated to the maximum-economy mixture.

Partial Vaporization in Manifold

MR. BREWER:—Is it your opinion that the fuel passes through the primary in the liquid state, or as vapor, or in what condition?

MR. KINDL:—Some vaporization does occur, depending upon the manifold depression, but under low depression such as open-throttle running, there is very little.

MR. BREWER:—With the small quantity of air, would

(Concluded on p. 617)

[15] Research engineer, Caterpillar Tractor Co., San Leandro, Calif.

[16] M.S.A.E.—Chief engineer, F. B. Stearns & Co., Cleveland.

Nitralloy in the Automotive Industry

By Hilton G. Freeland[1]

Detroit Section Paper

This special alloy, treated with nitrogen, is presented as having the following ideal characteristics: lack of distortion during nitriding and permanence of contour thereafter, great hardness, high resistance to fatigue and low coefficient of friction.

The constitution of the metal and its properties before and after nitriding are presented, and procedures and precautions necessary in heat-treating, machining and nitriding are explained. Methods are given for controlling the hardness and depth of case and for local protection against nitriding, and the time required for treating representative parts is stated.

Discussers of the paper showed interest in the cost, both present and prospective; in rust prevention; in the production of gages of great hardness and in the processes used for fabricating sleeve-valves from the metal. The author gives answers to questions on these subjects.

SELDOM are the wishes of the metallurgist and the requirements of the manufacturer so nearly realized in any one steel as they are in Nitralloy. True, we have encountered difficulties in applying it, and much more is unknown concerning it than is covered by our present knowledge, but we have seen enough of its application to the automotive industry to know that it possesses possibilities that will amply repay investigation.

This alloy possesses characteristics that require an adjustment of old standards and a forming of new ones. When treated, it has a surface hardness equivalent to from 1000 to 1200 Brinell, while the best commercial results obtainable with a carburized steel are in the neighborhood of 700. Yet our tests on crankshafts show that this steel is not as brittle as we might expect from past experience with extremely hard alloys but possesses high core physicals and a case that can be cold-straightened and will afterward resist fatigue to a degree previously unknown. This is a steel that fascinates us because of its possibilities and the incentive it gives to explore the unknown.

Origin of the Steel and Process

Nitralloy is protected by two patents issued to Dr. Adolf Fry, of the Friedrich Krupp Aktiengesellschaft, of Essen, Germany. Aubert & Duval Freres, of Paris, France, control the United States letters patent under which the Ludlum Steel Co. and the Central Alloy Steel Co. are licensed. The process covered is the nitrogenization of steel below the temperature of "peritectodial transformation". This temperature in some cases is as low as 580 deg. cent. (1076 deg. fahr.). The type of steel is one containing up to 0.6 per cent carbon, from 0.5 to 2.0 per cent aluminum, and from 0.5 to 4.0 per cent of an element or combination of elements having the properties of chromium.

The elements mentioned as suitable substitutes for chromium are silicon, manganese, nickel, molybdenum, tungsten, vanadium, titanium and zirconium, which may be used separately or in any desired combination.

Dr. Fry recognized the need for a steel that should have the minimum distortion upon hardening. This steel should have high physical properties and great surface hardness without undue brittleness, and the properties of the surface should be retained at usual service temperatures; it should be readily machinable and be capable of heat-treating to produce the surface hardness by some commercially practical method. Dr. Fry concluded that both high-temperature heating and the subsequent quenching should be eliminated, if possible, to reduce stresses and distortion.

His investigation solved the various problems step by step, until production of the alloy and its treatment were rendered possible. After determining the practicability of hardening the surface of steel by the use of nitrogen, the next step was to determine which nitrides would be most stable and which alloying elements would be most conducive to the penetration by nitrogen. Aluminum nitrides were found to resist dissociation until very high temperatures were reached, and molybdenum was found to eliminate any tendency toward temper brittleness and to increase resistance to shock.

Composition of Two Available Grades

The composition of G and H, the two grades of the steel, now in use in the United States, is shown in Table 1. The variation in carbon content changes the physical properties of the core, and this renders the steel suitable for a large variety of uses. The lower carbon is better where rapid-machining or deep-drawing properties are required. The silicon is usually below 0.30 per cent.

The aluminum is best when not lower than 1.00 per cent, to assure uniformity of nitriding results and the greatest hardness. The aluminum is alloyed with the iron and is not desired in the form of aluminum oxide. Molybdenum is very beneficial, giving a tougher core and case and removing any possibility of temper brittleness which might be caused by slow cooling of the charges from the nitriding temperature. Molybdenum apparently reacts against the formation of a brittle nitride layer and also possibly improves the depth of penetration. Until more is known about the effect of

[1] Sales metallurgist, Ludlum Steel Co., Detroit.

nickel, it is held as close as possible to the minimum.

For some applications, such as rolls for forming steel strip, bearings, and tappets that require high resistance to impact, cores are needed that will support higher unit stresses than present alloys can withstand. Considerable work has been done to this end by Dr. Fry, and I have been informed that a nitriding steel is now being used in Europe which contains in the neighborhood of 3.00 per cent chromium, 0.75 per cent vanadium and 0.40 to 0.45 per cent carbon. We are now investigating the possibility of making this alloy in America.

Physical Properties

From the foregoing it can be seen that Nitralloy has properties which will be of special service to the automotive industry. It is a steel having the minimum distortion after nitriding, provided the stresses caused by processes such as forming and machining are relieved before nitriding, and it possesses great surface hardness without being unduly brittle if previously heat-treated to produce a sorbitic structure. This same treatment increases its resistance to impact. The great hardness is accompanied by a naturally low coefficient of friction, which not only reduces wear but even permits metal to be run in direct contact with aluminum alloys; and it has been found that two unlubricated surfaces of the steel will run against each other under a pressure of 200 lb. per sq. in. without scoring. This property has been tested up to hundreds of thousands of reversals.

One distinctive property is that the hardness does not seem to be affected up to a temperature of about 1000 deg. fahr. Some growth is caused by the absorption of nitrogen during nitriding, but this is small and uniform for any given set of conditions, so that it can be calculated and allowed for in machining or grinding, to make the finished part of the required dimensions after nitriding. The physical properties are high, being controlled by the alloying elements and the amount of carbon. Table 2 shows the physical properties of Grade G quenched in oil from 1650 deg. fahr. and of Grade H quenched in oil from 1750 deg. fahr., both drawn for 1 hr. at 1200 deg. fahr. The Brinell reading after annealing at 1450 deg. fahr. is shown also.

Freedom from Corrosion and Distortion

The most satisfactory results in machining are obtaining when the Brinell reading is between 190 and 210. The cutting angle of the tool should be more acute and the speed higher than for an ordinary alloy steel of similar type. This will not only improve the cut but will, according to Dr. Fry, give normal production results.

Although this steel cannot be classed as a stainless steel, it has been found to resist the attack of fresh water and, to a considerable extent, of salt water, provided the original nitrided surface is not removed by grinding, although it may be lapped a little. The steel must be of the best possible grade and sufficient time must be allowed for nitriding if the results are to be of the best. Another property brought about by nitriding is that of retaining its dimensions indefinitely. Holding the steel at the nitriding temperature, between 900 and 1000 deg. fahr., relieves all stresses, so that the usual effects of aging do not appear. This quality is of very marked importance in gages and in parts such as crankshafts.

TABLE 1—TYPICAL PERCENTAGES OF ALLOYING ELEMENTS IN NITRALLOY

Grade	G	H
Carbon	0.360	0.230
Manganese	0.510	0.510
Silicon	0.270	0.200
Aluminum	1.230	1.240
Chromium	1.490	1.580
Sulphur	0.010	0.011
Phosphorus	0.013	0.011
Molybdenum	0.180	0.200

TABLE 2—PHYSICAL PROPERTIES OF HEAT-TREATED NITRALLOY BEFORE NITRIDING

Grade	G	H
Yield-Point, lb. per sq. in.	120,000	103,000
Tensile Strength, lb. per sq. in.	138,000	122,000
Elongation in 2 In., per cent	20.0	21.5
Reduction of Area, per cent	60	67
Charpy Test, ft-lb.	44.0	59.2
Brinell, 10 Mm. Ball, 3000 Kg. Pressure	285	255
Brinell, after Annealing	186	157

Dr. Fry, when in this Country, pointed out that an ordinary crankshaft, even with all the care used in finish-grinding, will change in shape after being run in an engine, whereas a Nitralloy shaft, even if not straightened after nitriding, will be straighter than the former after running. He also suggested that straightening an ordinary crankshaft while cold will put a kink in it which is far more harmful than the bow encountered after hardening, and suggested that tests be run to verify this. If this is true, less grinding after hardening would decrease present costs and improve the results obtained. Actual production tests have shown that shafts of the nitrided alloy steel can be straightened cold within reasonable limits without detrimental effects. One automobile company cold-straightened a crankshaft and then subjected it to an accelerated fatigue-test. This shaft showed no indications of failure and exceeded many times the results previously obtained, under best conditions, for the company's own alloy shaft.

The surface hardness of the case can be raised or lowered by changing the nitriding temperature, and the depth of case can be varied by changing the length of the nitriding time. As the temperature of nitriding is increased, the case hardness is lowered and the depth of penetration is increased for a given nitriding time. The value of this is apparent. The Humphrey slow-bend machine shows that a nitrided case, of the type at present in use, will bend farther before failure than will a chromium-nickel or a 5-per-cent-nickel steel, carburized and hardened, and that nitrided specimens heated to 1200 deg. fahr. after nitriding are the tougher. The case can be softened by heating nitrided parts above 1000 deg. fahr. for a time, higher temperature having a greater softening effect. This probably is brought about by diffusion and perhaps to some extent by dissociation, the deeper cases reacting more slowly.

Application and Possibilities

It can be seen that this steel has many possibilities. It is being used in this Country for pump shafts, steering-gear sectors, valve guides, oil-pressure regulators and many small parts for automobiles, and in aircraft for camshaft gears and for control bushings, pins and bolts in which resistance to wear is essential.

A large number of parts either have been approved and are going into production soon or are in course of test, among them the following: piston-pins, valve-push-rod rollers and roller pins, valve sleeves, camshafts, bevel-drive gears, transmission gears and timing gears.

Nitralloy has proved successful in other applications. One is for valve trimmings operating under high steam-pressure, in which use it appears to stand alone because it will operate under high pressures and temperatures without scoring and is not affected to any marked degree by the corrosive and erosive action of the steam. Another application is for sprayer valves working at pressures of 400 to 500 lb. per sq. in. against such liquids as Bordeaux mixture. Bearings for core ovens are also now made with balls of this steel.

Many of the moving parts in aircraft engines are of Nitralloy, including cylinder linings for the Hispaño-Suiza engine. Almost no wear is claimed for these cylinder-walls, and the oil consumption is said to remain the same throughout the life of the engine, or at least over a period of many hundreds of hours. The steel is also used in the best cars in Germany and France wherever it is practical, including bevel-drive gears and transmission gears. Superior results are claimed for valve push-rods made of it, although we have not yet been successful in this Country with this application, but have had some very good results and believe it will be practical in the near future.

HILTON G. FREELAND

Heat-Treating Method and Temperature

The heat-treatment is not complicated. Usually, heat-treating of the steel before finish-machining or grinding is best, unless the nitriding is done simply to prevent wear and the part will not be subjected to considerable stresses or to service which will develop fatigue of the part because of either impact or vibration. No heat-treatment is necessary if high physical properties are not needed in the core. The treatment generally consists of a quench from a temperature of between 1650 and 1750 deg. fahr., depending on the grade of the steel, size of the section, conditions of forging and other conditions. The quench is in oil or water, usually oil, and is followed by a draw at a temperature above the nitriding temperature. This drawing temperature is determined by the physical properties required.

It is recommended that the parts be machined or ground either to size or very close to size before nitriding. They should be heated to about 1100 to 1200 deg. fahr. after rough-machining, to let down the machining strains. Parts then will not become distorted after finish-machining or finish-grinding and nitriding, but will increase uniformly in size by a small amount. The amount of distortion is controlled by the extent to which the stresses are relieved before nitriding. The growth is slightly more at the end of a cylindrical section, because of nitrogen penetration from both the side and the end. The difference is apparent only on measuring and can be eliminated by slightly relieving the corners.

The process of nitriding consists of heating the work in a closed chamber at a temperature above the dissociation point of ammonia, which is 450 deg. cent. (842 deg. fahr.). The most satisfactory range according to present usage, is between 950 and 1000 deg. fahr. The work is placed in a box equipped with an inlet and an outlet for the ammonia gas, which decomposes into nitrogen and hydrogen. Some of the nascent nitrogen is absorbed by the parts, producing a concentration of nitrides that is high at the surface and diminishes gradually toward the core. The depth is proportional to the time, 90 hr. at 950 deg. giving a case depth of around 0.032 in., and is also considerably affected by the temperature, the higher temperatures producing an increased depth of case.

Control by Temperature and Time

The hardness, as previously stated, decreases somewhat as the temperature increases, so that the case hardness of work nitrided at 1000 deg. will be less than when 950 deg. is used. Indications are that the higher temperatures, especially those considerably above 1000 deg., tend toward decarburization, because of the liberation of more hydrogen, and toward greater growth with more liability of distortion. A double nitriding cycle has been suggested but has not been worked out to a practical basis. Heating the work first at 950 to 1000 deg. fahr. for a given time and then continuing the nitriding at about 1100 deg. will produce a deeper case than can be obtained by heating at the lower temperature for the total time. This method would shorten the nitriding time, but the results must be carefully checked experimentally before it will be safe to use in production.

Nitriding time is important because of its effect on cost. The tendency has been to use long nitriding cycles, to assure cases of sufficient strength to support the loads to be imposed without breaking the surface, and we realize now that this has been overdone in many instances. The case is very tough and strong when the nitriding has been correctly done and will not crack or show any tendency to spall unless the yield-point of the core is exceeded. Nitrided test-pieces that have been broken in tensile tests show concentric rings where the case has let go, but no indications of flaking.

Phonograph needles of great hardness have been produced by nitriding for 1½ hr.; small spindles are nitrided from 2 to 4 hr.; various bushings from 10 to 20 hr.; pump-shafts and piston-pins, 20 to 30 hr.; crankshafts and camshafts, 30 to 40 hr.; and various sectors and gears require 40 to 60 hr. These figures show that the length of nitriding time is not now so formidable, and it will no doubt be further decreased as we acquire

more experience in the nitriding treatment and learn more about the correct composition of the steel required for different applications.

Details of Treating Parts

Work is dumped directly into the furnace container, in some cases, with no attempt to pack it and no evil effect at the contacting surfaces, but this practice would not be recommended for parts having flat surfaces which might come together and entirely exclude the gas-flow. Dehydrated ammonia gas, which can be procured readily, is the source of the nitrogen used. Air must be kept from the work during nitriding, and the work must be cooled down to a low temperature before the furnace or container is opened. These precautions aid greatly in producing work of uniform hardness and free from discoloration. The nitrided parts should have a satiny gray finish.

After the work is placed in the box or nitriding chamber of the furnace, the ammonia is turned on to drive out the air and then the work is heated to the nitriding temperature. At the end of the time necessary for nitriding, the work is allowed to cool to about 300 deg. fahr. before unpacking, the ammonia continuing to flow during all this time. The flow of ammonia gas should be uniform and continuous and the temperature kept constant. The process is simple, the only precautions being that the work be free from decarburization and from all cutting compound, grease or dirt that might interfere with nitriding.

It should be emphasized that sufficient stock must be removed before nitriding to eliminate all surface oxidation, either of the material as received or as a result of subsequent forging or heat-treatment. Any trouble experienced with nitriding results can usually be traced to this source. The nitrided surfaces of decarburized steel spalls off and the surface hardness is not uniform.

If only certain sections of a piece are to be nitrided, the part may be dipped in a bath of molten tin or solder, the excess tin wire-brushed from the surface, and the tin machined off from the surfaces to be nitrided. Care must be taken that no tin drops off the work onto the parts below in the nitriding furnace. The surfaces that are to remain soft may be nickel-plated instead, but care must be taken to get a dense plate having a minimum depth of 0.0005 in. Tin-plating the portions to be retained in the soft condition is the most rapid, positive and economical method. Surfaces to be hardened by nitriding can be lacquered before the tin-plating is applied, the lacquer being subsequently removed by some solvent before nitriding.

Plant Equipment Required

The only special equipment required is that pertaining to a furnace for nitriding. Even the special furnace can be dispensed with and a box made of a chromium-nickel alloy or of Monel metal can be used, but a furnace specially designed for the purpose is most practical. The Leeds & Northrup furnace is of the pit type and has a fan at the bottom to cause rapid and positive contact of the gases with the work. A similar principle could be applied to a horizontal furnace, which would be more satisfactory for parts such as crankshafts and camshafts. One builder of furnaces informed me that he has designed an electric furnace of the continuous type, which should be particularly useful for parts such as brake-drums.

Experience so far has indicated that the ammonia and dissociated gases have little if any effect on the electric heating-elements usually employed, and the adaptability of electricity to automatic control has caused this method of heating to be almost universally adopted. The tank of dehydrated ammonia is so placed that gas and not liquid ammonia will be fed from it. The ammonia is conducted through rubber tubing to the nickel inlet-tube of the box or furnace chamber, where it is dissociated.

The most satisfactory rate of dissociation is between 20 and 40 per cent, as determined by a dissocation pipette which is connected to the exit tube by a bypass. The pipette is filled with the gases; then water is admitted, which flows into the pipette until all the ammonia is absorbed. The pipette is so graduated that the percentage of dissociated gases can be read directly. In most cases this is maintained at around 30 per cent. The outlet of the box or furnace chamber is connected to a bottle containing water through which the escaping gases pass. This indicates the rate of flow and furnishes a slight back-pressure for the furnace. The exit tube is connected from here to a drain, or the gases are conveyed to the outer air. The Hoke ammonia-control valve seems to have given most satisfactory results. A gasket of asbestos wrapped with aluminum foil will form a good seal if a box is used, and oil can be used to seal a pit-type furnace. Pyrometer control is essential because of the marked effect of small variations in temperature, which should be held within plus or minus 10 deg. fahr.

Costs and Road to Utilization

The cost of the ammonia required for nitriding is small. The cost of furnace heat is determined to some extent by the efficiency of the furnace. The nitriding time is longer than the usual carburizing time, but this is being shortened as we learn more regarding the process of nitriding. One automotive company, which uses large quantities of Nitralloy, ascertained that the cost of nitriding a given part did not exceed the cost of carburizing and hardening corresponding parts. I believe this to be true in most cases if reduced losses from rejection of parts are taken into account. The base price of the alloy is higher than the prices of many of the steels at present in use, but it will be found preferable when account is taken of the improved quality of the part and the savings that result from reduced grinding, less rejected parts and elimination of straightening and grinding operations.

To make this steel of great service in the automotive industry, it will be necessary (*a*) for the automobile and aircraft-engine manufacturers to assist the steel mills in determining the most suitable applications (*b*) for existing manufacturing practice to be modified in some cases, perhaps, and (*c*) for the steel mills to produce Nitralloys suitable for the various uses and determine manufacturing practices best adapted to meet the varying requirements.

Those who desire further and more detailed information on this subject are referred to the papers[3] given at the Nitriding Symposium of the American Society for Steel Treating in Cleveland in September, 1929. I gratefully acknowledge information procured from this source.

[3] See Nitriding Symposium, special edition of the *Transactions of the American Society for Steel Treating*, October, 1929.

THE DISCUSSION

J. E. WELLS[3]:—What is the thickness of tin-plating required as local protection against nitriding?

HILTON G. FREELAND:—Experimenting is necessary to determine just how thick the coat should be for the various applications, but it would be very, very thin. I understand that the plating time for some jobs in Europe is only a few minutes.

J. H. HUNT[4]:—When I looked up this subject some time ago there was a serious difference in cost between Nitralloy and other steels. What is the difference in cost now?

MR. FREELAND:—The present base price is 8 cents per lb., while the steels it would replace probably cost from 2¾ to a little more than 4 cents per lb. To offset this additional cost, many savings are made by avoiding loss from grinding checks and by more economical finishing of the parts; for instance, the machining of parts can often be completed in the soft state, unless lapping is required after the nitriding. The nitrided surface is gray, with the appearance of satin, and much smoother and more perfect than the surfaces of parts that are carburized or hardened.

MR. HUNT:—Was any special treatment given to the surface of the material that was run up to a bearing pressure of 200 lb. per sq. in. without scoring?

MR. FREELAND:—I understand that the test was made at the plant of the Westinghouse Electric & Mfg. Co., and that the surface needed only to be lapped to a smoothness that would be regarded as satisfactory for any bearing surface. I think that the result was possible because of the low coefficient of friction resulting from the extreme hardness.

A VISITOR:—Do you know whether the liners of Hispaño-Suiza cylinders are made from tubes or steel forgings?

MR. FREELAND:—I understand that they are forgings and that the forging is tinned all over and the bore of the cylinder section is finish-machined, the bore then being nitrided and lapped, after which the outside, still soft, is given the usual machining operations.

Welding Not Yet Successful

A VISITOR:—What would be the effect of lap or butt-welding to produce hoops or bands?

MR. FREELAND:—Welding has not been entirely successful so far, but the problem is being investigated and the near future may see the solution. I presume that the main difficulty is the presence of such a large amount of aluminum.

MR. WELLS:—Is a radius needed where a fairly sharp corner is desired for a gage; if so, what radius would you suggest?

MR. FREELAND:—I cannot tell just what radius would be required, but it could be very small, because the greater growth on the corners is not visible and can be determined only by measurement.

MR. WELLS:—I am thinking of brittleness rather than size.

MR. FREELAND:—It is not always necessary to relieve the corners to prevent brittleness, but the practice is good. Brittleness is more often a result of incorrect nitriding and heat-treating.

MR. WELLS:—What is to be done to reduce brittleness when work requiring a short nitriding period must go in with other work that is running through the furnace in 48 or 60-hr. cycles and the furnace cannot be run for the treating of these pieces only?

MR. FREELAND:—In that case I recommend quenching the steel and drawing it back, even though it is not necessary to develop the physical properties. By so doing you will be less likely to have a brittle nitride structure. Great discretion should be used in cases of this type.

F. G. SHOEMAKER[5]:—Is there any likelihood of the nitriding process being successfully applied to ordinary steels that do not contain aluminum?

MR. FREELAND:—Any steel can be nitrided but the results are not satisfactory without special alloys. The case is thin and lacks uniformity. Aluminum, in the form of aluminum, not alumina, seems to be the principal factor in nitriding steels.

MR. SHOEMAKER:—Assuming that Nitralloy could be used very extensively for such parts as gears and crankshafts, is the cost of the basic material likely to be reduced to about the same as that of other alloys? Is it inherently more expensive than other alloys used in the automotive industry?

MR. FREELAND:—I imagine that that possibility exists. Nothing will bring down the cost of raw material like production. However, more care is needed in the production of Nitralloy than for the usual alloy steel, because of the aluminum content.

MR. SHOEMAKER:—What precautions are necessary where stresses are concentrated, as at the fillets where the crankpins join the crank cheeks; is it necessary to prevent the formation of the hard surface on these fillets?

MR. FREELAND:—I should not say that it is, although many of these points have not been determined. No crankshafts of this alloy are in production now in this Country, although they have been fundamentally approved in a number of cases. The entire crankshaft has been nitrided in some cases, with no special safeguards against brittleness, and such shafts have showed no indications of failure.

Producing Hard Gages

GEORGE CHARLTON[6]:—We made some plug-gages from Grade G, with only 30 hr. of nitriding; they were intensely hard but they did not wear well. The treatment consisted of quenching in oil from 1650 deg. and drawing back to 1300 deg. The nitriding temperature was 950 deg. fahr. What did we not do that we should have done?

MR. FREELAND:—Was the nitriding done in a furnace having a forced flow of gas?

MR. CHARLTON:—No.

MR. FREELAND:—That is one thing which I would recommend, for two reasons: without an impeller, the flow may be too slow and hydrogen accumulation on the surface may prevent proper nitriding; while with impelled gases more atomic nitrogen contacts with the work in a given time, with consequent increased nitrogen absorption.

MR. CHARLTON:—Do you think it would be better to

[3] Assistant sales manager, Ex-Cell-O Tool & Mfg. Co., Detroit.

[4] M.S.A.E.—Patent section, General Motors Corp., Detroit.

[5] M.S.A.E.—Research engineer, powerplant section, General Motors Corp. Research Laboratories, Detroit.

[6] Wilcox-Rich Corp., Detroit.

use a lower drawing temperature, say 1150 deg. instead of 1300 deg., to leave the core harder?

MR. FREELAND:—I do think that would be good, because the nitrided case would have better support on account of the higher physicals resulting from the 1150-deg. draw. Did you take a Vickers hardness reading?

MR. CHARLTON:—No, only a file test.

MR. FREELAND:—The hardness may not be as great as you think. I should suggest checking it with a Vickers instrument.

MR. CHARLTON:—We have had wonderfully good wear from other nitrided parts. Can you suggest something that will give us better results on plug-gages?

MR. FREELAND:—You should be able to get a hardness reading of 1000 to 1200 Brinell, as determined by the Vickers instrument, without undue brittleness, and that should make a wonderfully good gage. I should recommend doubling the nitriding time, making it 60 hr.

M. A. TRISLER[7]:—Why does slight grinding destroy the corrosive resistance when nitriding penetrates to a depth of 0.010 to 0.030 in.?

MR. FREELAND:—I cannot answer that question definitely, but the great resistance may be due to the high concentration of nitrogen that exists at the surface. Piston-pins that are only slightly lapped after nitriding have given good results in salt-spray tests.

MR. TRISLER:—How much can be removed by lapping or grinding without sacrificing corrosion resistance?

MR. FREELAND:—I believe various conditions determine that. I know of parts that were nitrided for about 90 hr., and the removal of 0.05 mm. (0.002 in.) was sufficient to destroy the resistance.

[7] Jun.S.A.E.—Engineer, Holley Carburetor Co., Detroit.

Cold Carburetion

(*Concluded from p. 611*)

there be any appreciable vaporization of the fuel?

CHAIRMAN MOCK:—Using Dr. Bridgeman's tables, I tried to estimate the temperature of a dry mixture with a 4:1 air-gas ratio, and it came out about 30 to 40 deg. fahr. higher than it would have done with a 16:1 ratio. There must be some evaporation, of course, but, not having worked with this myself, I cannot even give a guess as to how much.

MR. BREWER:—Do you think that, by feeding a super-saturated vapor of that kind, we could get along without heating the throttle?

CHAIRMAN MOCK:—I should want to put on some heat if I were to fly in the machine myself.

LEROY V. CRAM[17]:—One bit of meat in Mr. Kindl's paper goes right back to the basic problem of this whole carburetion subject; that is, the difficulty he had in calibrating the individual jets for the individual primary tubes because of the effect of eddy currents and the like. We do not know anything about the pneumatics of flow through unsymmetrical passages, and we know even less about this when we have gasoline or some other liquid fuel with the air. I defy anyone to design a new carbureter and a new manifold and come close to hitting the desired results the first time.

Would Avoid Airplane Throttle-Freezing

MR. KINDL:—Although no work has been done on the use of cold carburetion on aviation engines, this seems attractive from the aspect of possible improvement of the freezing problem and from the fact that the accelerating problem is comparatively easier; it is not necessary to kick the throttle open at 5 m.p.h. in high gear and involve a lot of transient conditions that exist and are a great part of our problem on the motor-car.

S. M. UDALE[18]:—I rather take issue with that statement that acceleration is not necessary to aircraft. I have had experiences such that I would not be here if the engine had not picked up promptly when the throttle was opened quickly.

As for the freezing at the throttle, we found during the war that by delivering the fuel between the throttle and the cylinder, all freezing at the throttle was eliminated. I think that Mr. Kindl's development is absolutely on the right track as far as aircraft is concerned. Once the fuel is admitted below the throttle, we have to combat this freezing proposition at the throttle. The only way to do that is to add heat, and it probably will be necessary to add more heat than is needed if the fuel is admitted above the throttle.

MR. CAMINEZ:—Have you any figures, Mr. Kindl, on how much the compression ratio can be increased?

MR. KINDL:—The only figure I remember definitely was on a present six-cylinder engine, the compression of which was raised 7 per cent to get the same detonation. That would change the compression ratio. I think 3/32 in. was taken off the cylinder-head.

J. B. MACAULEY, JR.[19]:—Mr. MacCoull has just suggested to me another method of effecting considerable improvement in distribution; that is, not by adding heat to the manifold but by taking heat away from other parts of the fuel system where we do not want it. There are commercially available, at a price not in excess of the heavier fractions of gasoline that we are now using, large quantities of light gasolines which cannot be used at present because there is too much heat in the fuel system and trouble is experienced because of vapor lock. If the heat were kept in places where we want it, substantial improvement in distribution could without doubt be made by designing fuel systems that would enable the refiner to use these large quantities of lighter gasolines.

MR. WILLIAMS:—I believe there would not be as much trouble with the carbureters as with the gasoline tanks in which such fuel would be shipped.

MR. KINDL:—Considerable credit for the progress in this development should be given to Messrs. Teeter and Aseltine.

[17] M.S.A.E.—Assistant chief engineer, Chevrolet Motor Co., Detroit.

[18] Patent attorney, Holley Carburetor Co., Detroit.

[19] M.S.A.E.—Experimental engineer, Chrysler Corp., Highland Park, Mich.

Prevention of Fires on Motorboats

By H. E. Newell[1]

Motorboat Meeting Paper

WHEN an industry manufactures a product containing inherent hazards, obviously its duty is to safeguard these hazards so far as may be practicable. This, of course, is an obligation due the purchasers of the product and the public in general. As an illustration, the automobile has been so safeguarded against the fire and explosion hazard inherent in gasoline that today bona-fide automobile fires are relatively few. Similarly the airplane is now the subject of intensive thought along the same lines. I am chairman of a committee formed to draft rules for fire extinguishment on airplanes, and other committees are providing for safety in design and installation of engines and proper construction and installation of fuel tanks, gasoline lines, electrical devices and wiring. Many industries have inherent hazards that must be safeguarded and in the last 10 years my work has brought me in contact with manufacturers of pulverized-fuel equipment, oil burners, oxy-acetylene welding and cutting equipment, acetylene house-lighting and many other lines. Every manufacturer comprising these industries realizes to the fullest extent that any accident, involving personal injuries or loss of life and due directly or indirectly to a defect in design, construction or installation, adversely affects his own business and the industry in general in a financial way. This, of course, means a loss of confidence on the part of the public, a feeling that the product is unsafe.

> Producing an article that contains inherent hazards imposes upon an industry an obligation to protect purchasers and the public.
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> Gasoline is the principal inherent hazard in a motorboat, and ignorance, on the part of motorboat designers, constructors and operators, of such properties as its low flash-point, ability of a small quantity to render large volumes of air explosive, greater density of gasoline vapor as compared to air and the fact that this vapor can ignite at a distance and flash back to the tank is responsible for numerous fires and explosions.
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> Fires can be extinguished or their spread retarded by adequate equipment, but adequate and positive ventilation to carry off gasoline vapors as soon as they are liberated and constant watchfulness to detect and remedy leaks in fuel piping are the chief preventives of explosions.
>
> Filling fuel tanks introduces a hazard that can be overcome by developing a standardized screw-connection to which the hose can be attached.

In the last 20 years the rapid increase of motor power afloat has been truly remarkable. While this growth undoubtedly is due in large part to the energy and initiative of engine and boat manufacturers, a sad commentary is the increase in fires and explosions that has kept substantial pace with the increase in production. In my opinion this can only be explained on the ground of failure to sense responsibility properly, combined with a sacrifice of safety in the interest of production and possibly supplemented by at least partial ignorance of the true extent of hazards involved.

The motorboat, because of its design and construction, facilitates the bringing into the active state the inherent hazards that are a part of it when these hazards are not recognized by proper safeguards. These boats are designed and constructed under the supervision of technically trained engineers, professional men who, because of their training, should understand something of the hazard of flammable liquids and vapors when in close proximity to sources of ignition.

Gasoline the Principal Inherent Fire-Risk

The outstanding inherent hazard of the motorboat is the principal liquid fuel, gasoline, which has a flash-point of —0.4 deg. fahr. This emphasizes the hazard of this particular fuel, because it means that at practically any of the temperatures prevailing in this part of the Country, ignition can be secured if the percentage of air present is suitable. As far as the motorboat problem is concerned, it means that unless good ventilation is provided almost any concentration of vapor likely to develop will be ignited if it reaches a source of ignition, as for instance a spark of any kind or an open light or flame. The explosion range of gasoline vapors is 1.4 to 6, which means that any quantity of air containing from 1.4 to 6 per cent of gasoline vapor is favorable for ignition. Considering the density of air as being equal to 1, that of gasoline vapors varies from 3 to 3.5, or expressed otherwise, gasoline vapors are 3 to 3½ times denser than air. This explains the tendency of such vapors to settle to the ground and accumulate in pockets formed by cabins, bilges and the like. In fact, the form and construction of a boat make it an ideal container or pocket in itself.

Let us now consider another property of gasoline vapor, its ignition temperature, which should not be confused with its flash-point, where a spark, open light or similar source of ignition is required. By the ignition temperature, however, is meant the temperature at which a proper mixture of vapor and air will ignite without the aid of actual fire. In the case of gasoline vapors this temperature of automatic or spontaneous ignition is approximately 536 deg. fahr., and varies somewhat according to the gasoline involved.

At ordinary temperatures gasoline continually gives off flammable vapors and a light or a spark at considerable distance from the material will ignite it through the medium of the vapor. Thus vapor has been known

[1] Engineer, National Board of Fire Underwriters, New York City.

to travel more than 300 ft. to a source of ignition and flash back to the point of origin. As a case in point the disastrous explosion that occurred at Ardmore, Okla., several years ago on a very hot day with little or no air movement is cited. A tank car containing a low-grade gasoline was standing in the sun on a siding close to the railroad station. The hot rays of the sun soon caused such expansion of the liquid and vapor within the tank car as to operate the safety valve and vapors issuing therefrom settled to the ground and gradually spread to and throughout the railroad station, across an adjacent street to a row of frame buildings and farther throughout other buildings in the block to a distance estimated to be at least 300 ft. from the car. At this extreme distance the vapor came in contact with means of ignition and the resulting explosion literally blew the railroad station and other buildings in the block off the face of the earth, at the same time killing and maiming many people.

Bear in mind that the vapor from 1 pt. of gasoline will make 200 cu. ft. of air explosive. Whether the mixture becomes a burning gas or destructive explosive depends upon the proportions of air and vapor. In addition we must remember that a proper mixture of air and vapor coming in contact with a highly heated surface, as for instance an exhaust pipe or portion of the engine itself, can readily ignite.

If these properties of gasoline were thoroughly understood and appreciated, much of the installation work about the motorboat would be greatly different than it is in many cases today. This ignorance on the part of the amateur and professional motorboat designer, constructor and operator is emphatically illustrated by the causes of fires and explosions that have occurred.

Fire-Risks of Equipment and Individuals

The type of galley equipment, often involving the use of high-test fuels, through faulty design or installation frequently causes a fire. In recent years the use of compressed gases in galley stoves has been accompanied by fires and explosions. These systems if properly installed and used undoubtedly reduce the normal galley hazard, but using, as they do, such highly volatile and flammable gases as propane and butane, which are practically casing-head gasoline, any leakage creates at once a highly dangerous condition.

Electricity is also an increasing cause of fire due to the constantly growing use of electrical equipment. In the light of numerous electrical installations that have come to my attention, the wonder is that the fire and accident record is not greater. This particular industry seemingly stands high in the good graces of kind providence.

And now we come to one of the most pronounced fire causes, the individual. Smoking in places where dangerous accumulations of flammable vapor are most likely to be found, looking for gasoline leaks with an open light and other types of carelessness characterize the fire causes from this source. Of course, the average motorboat operator has not experienced a fire or explosion and frequently this creates in him the feeling that such things never could happen aboard his boat. He often is of the type that resents advice of any kind and this know-it-all attitude has indirectly resulted in fires. Nevertheless he is simply exhibiting a human failing and he needs and deserves instruction in the rudiments of safety.

In 1929 numerous explosions on motorboats occurred immediately following fuel-filling operations. This is undoubtedly the most hazardous period of motorboating and often proper care is not exercised. Frequently the arrangement of the filler pipe is such that vapors or liquid gasoline escape undetected and become pocketed in a confined space near a source of ignition. This emphasizes the urgent importance of complying with the following recommendation:

> That all filler pipes to gasoline tanks be located on the outer deck, outside of cockpit and combings so that any overflow will run overboard; and further, that filler pipes extend to the bottom of the tank.

Study of Marine Regulations Would Reduce Hazards

I believe that this lack of understanding or ignorance, call it what you will, would be largely overcome if every designer, constructor and owner of motorboats was supplied with a copy of the National Fire Protection Association marine regulations. A thorough study of these rules would surely result in greater knowledge and improvement respecting the subject under discussion. These rules are not in any way insurance propaganda. They were adopted by the Association after a thorough study of present-day practice by a committee composed mainly of marine men in cooperation with all interested parties including the Technical Committee of the National Association of Engine and Boat Manufacturers. Of particular interest to engine and boat manufacturers is Appendix D of these Rules which relates to internal-combustion engines. A recital of the various paragraph headings will convey just what comprises this Appendix of the Rules. In the order of their arrangement these are as follows:

Gasoline Engines and Engines Using Gasoline for Starting

(1) Location, material and construction of fuel tanks
(2) Fuel piping
(3) Carbureter
(4) Exhaust
(5) Bilge
(6) Operation

General Requirements for Protection on Gasoline-Propelled Craft

(7) Hull arrangement
(8) Galley arrangement
(9) Electrical equipment
(10) Fire extinguishing equipment
(11) Kerosene

Diesel Engines, Including Solid-Injection Type

(12) Fuel tanks
(13) Piping
(14) Heating coils
(15) Purifiers
(16) Exhaust
(17) Boilers
(18) Electrical equipment
(19) Fire extinguishing equipment
(20) Auxiliaries
(21) Operation

Surface-Ignition Engines, Semi-Diesel or Hot Bulb

(22) Fuel tanks
(23) Piping
(24) Torches
(25) Exhaust

(26) Bilges
(27) Ventilation
(28) Fire extinguishing equipment
(29) Electrical equipment
(30) Operation

Attention is directed to revisions made in 1929 to that division of the Appendix dealing with gasoline engine and engines using gasoline for starting. These revisions provide more comprehensive requirements for venting of fuel tanks, elaborate further on piping and carbureters and, under general fire-protection requirements for all kinds of motor craft, provide more detailed rules for safeguarding galley equipment and such electrical apparatus as batteries and switches.

Adequate and Positive Ventilation Needed

Reverting to the discussion of the properties of gasoline, unless wholly adequate and positive ventilation is provided, dangerous accumulations of vapor will occur within the boat confines. This is practically assured and facilitated by the very form and construction of the craft itself. Any system of ventilation to be effective should be designed and arranged to collect and carry off safely the vapors as soon as they are liberated. Regardless of the service to which a boat is put, be it commercial or pleasure, its use is intermittent. This means that when the craft is not in service and with little or no supervision, pipe leakage will escape detection. In this way dangerous concentrations of vapor may be, and frequently are, present when the engine is started. Such a condition is an incentive for a ventilation system that can be operated previous to starting, thus insuring a gas-free and safe condition, which is a requirement of pronounced importance.

Mere pumping of bilges does not result in freeing such spaces of vapors; neither does overhead ventilation. The many underdeck fuel-tank vents and sounding holes result in nullifying correct fuel-filling arrangements. In this connection your attention is directed to the recommendations for the ventilation of engine rooms, prepared by E. D. Wright and A. C. Hutson, of the National Board of Fire Underwriters. They have received the unqualified indorsement of the U. S. Yacht Underwriters and are recommended to you as offering the best solution of this phase of the problem of ventilation. The recommendations, which have been substantially approved by the National Association of Engine and Boat Manufacturers, are as follows:

> Three-inch or larger ventilating pipes running down all the way to bilges should be placed in all four corners of the engine room. These should be made so that they cannot be closed. The little water that would enter in a heavy sea would be negligible in comparison with the danger of confined gasoline vapors. Two of these pipes should be provided with electric fans to remove gases from the bilges. If suction fans are used, the engine must be of explosion-proof type or located outside of fan duct. These fans should run for at least 10 min. before starting and after shutting down. Where boats are so small as to make an electric fan impracticable, the same pipes should be installed with the fans omitted.
>
> In still smaller boats where the installation of these ventilation pipes is impossible, an opening of not less than 36 sq. in. should be cut close down to the cabin floor in both forward and after partitions of engine room to induce a draft so that the heavy vapors which lie in the bilges can be forced out. No ventilation above either at deck or sides will remove these vapors.
>
> A ventilating cowl or port both in the forward and after ends of the boat should always be open so that a draft will be maintained throughout the boat.

The engine-room vapor hazard is increased by the practice of using therein open automatic switches and fuses. Sparks and arcs from this source offer an easy means for vapor ignition. With adequate equipment a fire can be extinguished or its spread retarded, but only means of prevention in the shape of adequate safeguards will prevent explosions; complete ventilation and constant watchfulness to detect and remedy leaks in fuel piping are the principal means for preventing explosions.

In conclusion, anyone who has given the motorboat problem mature consideration will agree that the remedy, so far as fire and explosion prevention are concerned, lies in eliminating physical hazards. This work should be fostered by engine and boat builders, carrying on an educational campaign among their customers and clients. As a suggestion for this purpose a booklet of instructions as to safe operation and maintenance and statements as to why safe types of equipment and apparatus are used and needed in their particular product will go far toward reducing the number of fires and explosions in motorboats. The National Association of Engine and Boat Manufacturers can best carry on this work because it is the mouthpiece of the motorboat industry and this is a duty that the industry owes the public. Underwriters' Laboratories has offered to cooperate with the industry and has tendered its services in the way of testing and listing apparatus and equipment for use in motorboats. The National Fire Protection Association, through its Committee on Marine Fire Hazards, has already shown a marked willingness to cooperate in a decidedly tangible way.

THE DISCUSSION

O. A. Ross[2]:—Some very disastrous results have followed the use of carbon-dioxide or carbonic-acid gas tanks in which a pressure-reducing valve or a safety valve was not used. As a result, the auxiliary tank, in which the gas is placed at a pressure of about 200 lb. per sq. in. for starting, has exploded and blown a hole in the boat, resulting in the loss of the craft and of life.

CHAIRMAN A. E. LUDERS[3]:—Do you refer to tanks for fire-fighting apparatus?

MR. ROSS:—I am referring to the tanks usually used for starting the heavier-type engines.

CHAIRMAN LUDERS:—I would say that the use of carbon dioxide for starting engines would be the exception rather than the rule.

MR. ROSS:—In many small cruisers the custom is to install a supply tank of carbon-dioxide gas compressed to about 1500 lb., the gas then being expanded through a

[2] M.S.A.E.—Consulting engineer, Ross Engineering Co., New York City.

[3] President, Luders Marine Construction Co., Stamford, Conn.

reducing valve into a small auxiliary-tank at about 100 lb. and used for blowing a whistle or operating auxiliary devices. If the reducing valve fails, the full 1500-lb. pressure is applied to the auxiliary tank, resulting in a terrific explosion that usually blows a hole in the boat's side and causes immediate sinking of the vessel. Many lives have been lost from this form of accident. If a safety valve is employed on the small auxiliary-tank as a precautionary measure, the gas will leak, causing waste and pollution of the vessel's interior air. My suggestion is that a safety plug including a thin metal disc that will rupture at 200-lb. pressure should be specified as part of the safety appliances for preventing explosion of the auxiliary tank. Whereas this form of explosion does not properly fall under the category of fire prevention, such an explosion might be the cause of initiating a fire and I, therefore, also suggest that the regulations for installing high-pressure carbon-dioxide tanks and apparatus should be included under the regulations for fire prevention.

Proper Ventilation Essential

LEONARD OCHTMAN, JR.[4]:—One of the really difficult things to work out in a boat is proper ventilation in the engine room and the bilges surrounding it. The points brought out in the paper with regard to ventilation are a step in the right direction, but will they be entirely adequate? First, we are relying upon the operator of the boat for proper ventilation by operating the apparatus before starting and after shutting down the engine. Second, no assurance is offered with the usual type of construction that after he has operated this apparatus for, say, 10 min. or so, the bilges will be entirely free of gasoline vapors. Another point that might be mentioned is that the engine itself is a very good ventilator, because it withdraws air from the engine room and uses it in running the engine. With carbureter-air intakes protected as many are now and with this protection rapidly coming into wide use, the engine becomes a really better ventilator than any ventilating system that you could ordinarily put on and expect to operate. One thought which this brings up is that the downdraft carbureters installed on many engines exhibited at the Show have the air intakes too high up to be really effective as ventilators.

To provide the greatest measure of safety some device to indicate the presence of gases in the bilges should be worked out. Just what form such a device would take I cannot say, but something that the operator could use, either mounted permanently or taken into the engine room, which would tell him whether the gases, down in the bilges particularly, contain sufficient gasoline vapors to be dangerous, would be a very big help in fighting this menace.

JAMES CRAIG[5]:—Ventilation is one of the most difficult problems that engineers have to deal with. In my mind that is because the matter to be regulated is very, very light, very agile and elusive, and an arrangement that might be effective in a room or a confine of a particular configuration would be wholly ineffective in another one. I am not posing as an authority, but I think that every facility should be employed to get the utmost ventilation.

If we utilize every facility to secure ventilation, we can reach a point where the mechanism becomes too heavy. We should take every possible care in the installation of mechanism aboard a boat to reduce the necessity for ventilation as much as possible, or rather bring the matter that is out of balance more nearly into balance in relation to what ventilation can accomplish. Ventilation cannot accomplish everything; it can only do so much, and beyond that it is powerless.

One pint of gasoline will liberate or make effective 250 cu. ft. of explosive gas. If we visualize 1 pt. of liquid, that is nothing in our average senses, but to witness the effect of 250 cu. ft. of explosive gas is most significant and behooves us to minimize the possibility of 0.01 pt. of gasoline getting into the confines of a boat. In addition, to afford a reasonable measure of insurance and security, the boat should contain elements of the best possible character of ventilation.

I have a word of praise to say for downdraft carbureters even though they are high up. I can conceive that we have only begun to use downdraft carbureters and the force that is effective at the orifice can be arranged so as to reach down into the confines and perform the service that the low down carbureter does now perform.

Engine builders in particular should strive to make effective the circulating forces that can be obtained from the flywheel of their engines and not just lock them up in a safe deposit vault and close them to all beneficial purposes. I remember engines years ago and some of them today I think are made with the spokes of the wheel of the propeller or exhaust fan type, which is an agent that will effect considerable circulation and at no great cost. Every possible facility should be used to provide most effective circulation within the confines of the boat. Boat and engine builders must not be held guilty for all the accidents we hear of in connection with motorboats.

Gasoline-fuel servicing-stations deserve considerable censure. To my mind very little thought has been shown in locating them in desirable places whereby motorboats can be replenished with fuel and with the least possible distraction and liability for spillage and the escape of fumes. I think that the prevailing gasoline filling-stations are just haphazardly dumped without any thought to the safety provision whatsoever and many other conditions that the motorboat encounters are all conducive to many of the accidents that occur. I thoroughly agree with Mr. Newell that one of the most hazardous periods in motorboat life is that attending and directly after the replenishing of the fuel tank.

Fuel Tanks Should Drain Overboard

MR. ROSS:—I know of several motorboats in which the lowest level of the fuel tank is placed above the water-line in a compartment that has no connection with any other part of the vessel, this compartment being drained to the sea. If any leakage or spillage occurs, it immediately drains overboard.

In these particular motorboats the engine has a vacuum fuel-feed and when the engine is stopped, all the gasoline in the system returns to the tank with the exception of what may be in the carbureter. The custom is to stop the engine by shutting off the gasoline and allowing the carbureter to drain dry. In this way gasoline cannot get to the bilge unless a defect exists to the gasoline-tank compartment which can be checked in a very simple manner.

[4] M.S.A.E.—Chief engineer, Elco Works of the Electric Boat Co., Bayonne, N .J.

[5] Advisory engineer to the Technical Committee, National Association of Engine and Boat Manufacturers, New York City.

CHAIRMAN LUDERS:—We in the industry have noted a slight backward movement in one respect with regard to the safety of motorboats and of which I am reminded when you bring up the subject of setting gasoline tanks in pans. Twenty years ago the almost universal practice was to put all gasoline tanks above the water-line and set them in copper pans that drained to the sea. In some cases the tanks were set in the bow of the boat and bulkheaded off by water-tight compartments with large and numerous holes through the skin of the boat for the circulation of the sea water and carrying off any fuel leakage. In those days few explosions occurred around the engine of a motorboat probably due to fewer inclosed cabin boats being built and more open space around the engine. With the advance of the art, people have demanded more accommodation and more machinery than in the earlier designs and we very seldom have the room to install an adequate gasoline tank with a pan above the water-line. Usually we have to go to all parts of the boat and put in gasoline tanks to carry the necessary fuel required by the tremendously high-powered engine installations used today. In a 60-ft. boat 20 years ago the engines averaged about 25 hp. Now we are installing as much as 1000 hp. in the same size of boat and with the increased conveniences and accommodation for the owner the tank space and engine room are inevitably restricted and engine-room ventilation becomes increasingly difficult and a serious problem for the boat and engine builders. Ventilation is the keynote in my estimation, of the whole problem but it is a difficult problem to solve.

Causes and Control of Gasoline Accumulation

E. GREENFIELD[6]:—What are the main causes that permit the accumulation of gasoline vapors in the bilge?

MR. CRAIG:—Gasoline tanks as they are put in motorboats seldom leak. When they do, they leak so profusely that this condition manifests itself. In a general way I do not think we are so deeply concerned with regard to the integrity of the tank.

The greatest hazard is when we are filling the tank and we have no control over the gasoline from the time it leaves the filling tube and enters into the filling orifice of the tank. The facilities for that gasoline to evaporate are remarkable and when it does evaporate, the vapor is from two and one-half to three times heavier than the atmosphere, which shows what facility, what power, what force this vapor has to insist on falling down and creeping into the confines of the boat.

I remember the tanks installed in the olden-time motorboats and they were placed in a compartment, the bottom of which was above the water-line, and they were laid in pans and all drip went overboard, but we would not stand for that today. We do not want any drip or leaking pans, but we have not, and we will not have, complete control of the gasoline while we fill the tanks until we unite in devising a standard screw-connection on the motorboat to which the filling hose will attach and then we shall have control of it right from the tank on the shore to the vessel.

MR. GREENFIELD:—I believe you are absolutely correct in saying that the filling period is the dangerous time. If you have a standardized direct connection between the filler nozzle and the gasoline tank and everybody uses the same filler-neck flanges on the tank and the same size of filler nozzle on the hose so this direct connection can be made, you will still have to vent the tank and displace the air in the tank. When you do that, the escaping gases will also become a dangerous factor. Am I right?

MR. CRAIG:—Yes.

MR. GREENFIELD:—Then you will have to control those.

MR. CRAIG:—Yes.

MR. GREENFIELD:—The Chris-Craft fuel-tank opening gives control, as the venting and filling operations are so protected that explosions are physically impossible. I have seen it tested by actually igniting the vapors as they emit from the vents, and nothing happens. If we have a direct connection, we have the vent which is a serious problem too, and even if we all standardize on the type of connection, that condition will still exist but I thought somebody could enlighten us on other causes that are responsible for the accumulation of gasoline and gasoline vapors.

The Protectoseal is a device composed of two cylindrical screens, one with the fine mesh on the outside and the other with coarser mesh on the inside, and an intervening air space. Both screens are attached to a collar that, in turn, is screwed into the head or neck, and together they make a very attractive and practical filler-neck flange and deck flange combined.

In the event of the vapors igniting as the gasoline enters the tank through that device, the flame in its effort to get through those two screens is cooled below the combustion temperature and dies a natural death right there. The nozzle can be readily pulled out, and the cap is arranged so that it snaps right back in place of its own accord, and it is secured by a spring. That device is approved by the National Board of Fire Underwriters and you cannot maintain fire in it, no matter how hard you try. To get fire to the gasoline tank when you are filling or when you have the gas cap open is impossible.

In the event of fire surrounding the tank, the heat that develops around the area of the tank generates considerable pressure, and, unless that pressure is relieved, an explosion will occur. With this device the cap opens as soon as pressure develops near the tank. It does not wait for this pressure to reach a certain number of pounds but releases it as fast as it is set up. I have seen one tank that was cherry red in the daytime, from a beautiful charcoal fire underneath, and the gasoline boiled out of it.

[6] American Safety Equipment Co., Detroit.

Outboard Engines

By JACOB DUNNELL[1]

MOTORBOAT MEETING PAPER

The first crude models of outboard engines were built about the same time that the gasoline engine was developed in other fields, but the first real forward step in design was made soon after the World War.

Racing engines weigh slightly over 2 lb. per hp., but total weight is very high. Small service-models for rowboats and canoes weigh much less. These are of the conventional two-cylinder opposed three-port type and form the backbone of the industry.

Cylinders usually have integral heads, but two models appeared last year with removable heads. Pistons are of the conventional two-cycle type with a baffle on the head to facilitate scavenging.

Manifolding usually consists of the simplest possible casting that will get the mixture from the carbureter to the intake port.

Four-cylinder engines have been developed to meet the demand for larger powerplants, but these are merely two of the two-cycle opposed-type units set one above the other. Although two four-cycle radial engines have been developed, very few have been built.

Standardization of the more important parts would not interfere with efficiency or performance and would simplify the problems of the boat-builder and the owner.

THE OUTBOARD type of engine for boats was conceived and the first crude models built at about the same time that development of the gasoline engine began to be felt in all other fields. In contrast to the automobile, the inboard boat, the stationary and many other types, the demand for the outboard engine was not large and its development was very slow. The reason for this was that this type of engine, by the very nature of its use, must be exceedingly light in proportion to its power and gasoline engines of those days came far from filling this demand. However, they were not thrown entirely into the discard and we saw an increasing number of experimental engines as well as a few so-called production ones between 1905 and 1910.

The first real step forward in outboard-engine design was the appearance in 1920 of a small light two-cylinder opposed type of relatively high speed. This had many features never before used in this field, such as the three-port design with a float-type carbureter, magneto built into the flywheel and opposed cylinders firing simultaneously to reduce vibration. Basically, this engine is unchanged today and is still very popular. This marked the beginning of the phenomenal development and popularity that outboard engines have enjoyed for the last 10 years.

Last year brought forth the first really successful engines to depart from the old accepted practice and design. This season we have seen revolutions increased 50 per cent, the power-weight ratio decreased and the introduction of drilled crankshafts, dual carburetion, mechanical valves, under-water exhaust and easier starting. The outboard-engine industry has realized that its old method of merely refining former models does not meet the demands of the public and from now on we should see rapid strides in development so that before long this type of engine should be as reliable as that in modern motor-car.

The American Power Boat Association definition of an outboard engine reads:

> A complete internal-combustion power and propulsion unit attached to the boat, which can be lifted by human power from the hull as one unit, excepting the battery for ignition and starting, tachometer, steering and throttle-control arrangements.

From this definition minimum weight per unit of power is seen to be the essential factor in design. We are accustomed to seeing, in the specifications of airplane engines, figures of 1½ or 2 lb. per hp. but we must remember that these are large units of over 100 hp. A 30-hp. outboard engine will weigh slightly over 100 lb., but if we strip off the drive unit, gasoline tank, muffler and similar parts, we will find that the engine proper weighs only slightly over 2 lb. per hp. Even at this the unit is too heavy to be lifted on or off a boat with any degree of comfort and for this reason these larger engines are used only for racing or for more or less permanent installation in larger boats. At the other end of the scale we have the small service-engines weighing from 27 lb. up which really form the backbone of the industry. They are easily carried about and will give from 5 to 10 m.p.h. on any rowboat or canoe. With reasonable care they give almost no trouble and will run for an almost indefinite period at full throttle. These engines are mostly of the conventional two-cylinder opposed three-port type with float carbureter and flywheel magneto. So far all outboard powerplants have been water cooled and in these smaller types a cam-driver plunger-pump located below the water level is the usual means of circulating the water, although one manufacturer uses the pressure-vacuum system that I will discuss later. We see here at the show one model of small service-engine that is radically different from any brought out before. It is really nothing more than a two-cylinder vertical engine set on end with the cylinders pointing aft. Its cylinders fire alternately, giving two power impulses per revolution where the opposed engines give only one. This not only gives better idling and smoother running but also much easier starting. On

[1] Manager of production and design, Ludington Aircraft, Inc., Philadelphia.

almost all outboard engines starting is effected by a short cord wound around a pulley on the flywheel. A quick pull on the cord snaps the engine over several revolutions and usually starts it, but if the engine happens to be balky, no better exercise can be found in the world.

On the larger engines, especially in the racing models, the variation between different models and makes is so great that I think discussing the different more essential parts by themselves will be more satisfactory. We will start from the top and go down. The flywheel consists of a cast aluminum shell containing the permanent field magnets of the magneto, which is an interesting point. This flywheel must be of non-magnetic metal and must, of course, be light, yet it must not only resist any bursting tendencies at, in some cases, over 6000 r.p.m. but also hold in place a fairly heavy steel magnet. The coils and breaker assembly are mounted on a plate inside the field magnet and by turning this plate the timing of the spark can be advanced or retarded. On the larger service-types we see the introduction of a single-unit starter and generator replacing the flywheel. This, of course, is a great improvement over the old rope starter, but adds 7 lb. to the weight, makes the engine much higher, and necessitates carrying a storage-battery in the boat.

Present-Day Cylinders

The cylinders are gray-iron castings usually with the heads integral with the barrels and completely water-jacketed. Two models appeared last year with removable heads that not only facilitated removing carbon but as the heads were cast of Lynite they ran very much cooler than the old type. The crankcases are of cast aluminum alloy with the main bearings pressed in. These bearings in the slower-speed engines are usually bronze bushings, while in the high-speed models they are balls or rollers with a short bushing on the outside to hold in the crankcase compression which amounts to about 3 lb. The lower main-bearing is, of course, oiled by the crankcase mixture that settles into it. The upper one, however, is lubricated in several ways, the most successful consisting of a tube or passage in the casting leading from a small sump in the bottom of the crankcase to the lower part of the top main-bearing. Another tube from the upper part of the bearing leads back to the intake manifold. This system forces oil to the bearing by crankcase compression and sucks it through, removing the extra oil by manifold suction.

The crankshafts are drop forged and are usually of the conventional type and uncounterbalanced. Two engines, however, appeared last year with a disc type of crankshaft that makes a more compact engine and is easily counterbalanced without the addition of any extra weights. This type also fills up more of the crankcase, giving a higher base compression. This year we see a still greater number of engines equipped with this type of crankshaft which seems more successful than the straight-throw type. One engine last year also appeared with a drilled crankshaft, but, instead of the orthodox pressure oiling-system, the lubricant was fed into the main bearings from drip cups and was forced out to the connecting-rod bearings by the centrifugal force of the revolving crankshaft. While this system worked very well on high-speed racing engines, it was not very effective at lower speeds, as the base compression tended to counteract the centrifugal force.

Connecting-rods on the smaller and the slow-speed models are usually of bronze with the bearings turned right out of the casting so that no separate bearings are necessary. In the higher-speed types, Lynite or steel is usually used. Some of the opposed engines have the cylinders directly opposite, in which case the misalignment of the crank throws is taken care of by an offset connecting-rod. This seems more satisfactory than the older method of offsetting the bearing at each end of the rod. However, neither will stand up on engines operating at high speeds as the rods tend to straighten out with use. Most of the higher-speed engines are slightly offsetting the cylinders so that they come opposite to the crankthrows, making the use of a straight rod possible. On these high-speed types, roller bearings are usually used in the connecting-rods. They are of the split-cage type, are held in position by a bearing cap similar to that used on a babbitt bearing and when used with a disc crankshaft, a ground face on the disc takes care of the end play of the rollers.

Pistons in all of the engines are of the conventional two-cycle type with a baffle or deflector on the piston head shaped so that the incoming gas will scavenge the cylinder as thoroughly as possible with no more waste of unburnt fuel through the exhaust port than is necessary. In the slow-speed models, the pistons are usually of iron with at least three rings, one of which is usually on the skirt. In the high-speed types, Lynite pistons seem to be the usual practice and two rings are used. At first these gave considerable trouble, due to the burning of the piston heads, but this was overcome by thickening the head so as to distribute the heat more evenly. In some of the early engines of this past year, I have seen a hole nearly $\frac{1}{4}$ in. in diameter burned directly through the piston head and parts of the melted metal in the exhaust port.

Simple Manifolds but Many Port Arrangements

Manifolding has not received any great attention in most of the engines and usually consists of the simplest possible casting that can be designed merely to get the mixture from carbureter to the intake port. The carbureters themselves have also been of very simple design, being of the float type with a single fixed-jet controlled by a needle valve with a constant air-supply going directly into the venturi. Dual carburetion appeared for the first time last year on some of the racing engines and while probably more efficient, to keep two carbureters properly synchronized on a two-cycle model is very difficult. On one engine this year we see a new type of carbureter that has no float chamber or valve, the incoming supply of gasoline being regulated by a diaphragm valve. From this valve, the gasoline passes through a needle valve to two jets that are removable and can be changed for different conditions. These jets contain small venturis to supply the constant air, while the main air is admitted through a dashpot and passes by the jets in a straight passage instead of a venturi.

The porting of all the engines varies greatly, not only between different manufacturers but also between each model of the same manufacturer. This, of course, is

really the heart of the two-cycle engine and a very slight change in port dimensions or location will completely change the performance. One manufacturer still adheres to the two-port system with a check valve on the intake between the crankcase and the carbureter. While this system is used on many slow-speed industrial and marine engines, it is not entirely satisfactory in higher-speed outboard models as designing a check valve that will operate properly when it is moving as fast as is necessary in these engines is impossible. Many of the other manufacturers use the three-port type in which the third or intake port into the crankcase is opened by the skirt of the piston on the compression stroke. This system is very positive, but as the port does not open immediately an appreciable negative pressure develops in the crankcase and as it stays open until long after top dead center, excessive blow-back through the carbureter may occur. Last year two models appeared with a mechanical intake-valve. These engines were of the two-port type with a rotary valve, driven by gearing from the crankshaft and placed between the carbureter and the crankcase. This enabled the manufacturer to time the opening and the closing of the intake valve at will and therefore the maximum charge could be drawn in with no possibility of blow-back. Some difficulty was experienced last year with a drive for this gear, but this has been overcome in some of the models by enlarging one of the main bearings of the crankshaft and drilling the ports directly through this. In other words, one of the bearings serves as a rotary valve without any extra moving parts and at the same time shortening the intake passage and making a more compact engine.

One of the greatest difficulties experienced last year by the racing drivers was with spark-plugs. In these new high-speed engines to obtain a plug that did not burn up or, if it was cold enough to withstand this, did not foul because of the oil in the gasoline was very difficult. The service on these spark-plugs is very much harder than in a four-cycle engine, since, as an explosion occurs every revolution, only half as much time is available for the plug to cool down. Also, the incoming gases have been heated by the base compression and do not cool the plug as effectively as the cool gases coming from the carbureter of a four-cycle engine. In addition the compression of these engines is unusually high and after a plug is designed to be cold enough to withstand these conditions, it very probably will become effectively fouled the minute the throttle is closed. Incidentally the compression ratio is about 6 to 1 after the exhaust port has closed, which is a higher effective compression than in most four-cycle engines.

An interesting device appeared on some engines which greatly facilitated the starting, particularly in the larger models that are hard to turn over with a rope starter. This is known to the trade as a release charger and consists of a relief valve in the head of one cylinder which is usually operated by a handle that is also connected to a rotary valve in the by-pass port. For starting, this handle is thrown into a position that opens the relief valve in one cylinder-head and at the same time closes the valve in the by-pass to the same cylinder. This means that when the engine is turned over, one cylinder being opened to the atmosphere, pulling against the compression of the other cylinder is all that is necessary. However, the full charge for both cylinders is taken into the crankcase in the usual way, but the by-pass valve being closed necessitates all this charge going into the other, or active, cylinder. In this way, this active cylinder receives nearly a double charge and therefore will fire more readily, especially when the engine is cold. This system also has an unexpected effect that materially helps it; one cylinder being supercharged, while the other is opened to the atmosphere, the active cylinder acts as a condenser to the spark, giving a much hotter spark than normal, which also facilitates starting.

Lower Unit of Engine

The mufflers on most of the older engines were merely two concentric sheet-metal tubes with perforations in them which did not line up with each other so that the whole acted as a double expansion-chamber. However, as everybody knows, these mufflers did very little good and caused considerable adverse comment on the part of residents of summer resorts where a number of motorboats were in use. Last year saw the introduction of the under-water exhaust which almost entirely did away with the troublesome noise always associated with an outboard engine. The mufflers used on these exhausts were a single cast chamber with cooling fins on the outside, or, in some cases, were completely water-jacketed. From this muffler, a tube ran down to the lower unit where the exhaust escaped through some form of opening facing aft and well below the water level. This would cause such back pressure when starting that some form of relief valve was necessary on all these engines. Last year these valves were manually operated, but this year some of them are automatically controlled by the flow of cooling water. At higher speeds, the suction caused by the water flowing past the exhaust outlet more than overcame any back pressure, but the added drag of this outlet in the water probably slightly diminished the speed of the boat. Possibly, in the future, however, they will be designed so that the increased power derived from exhaust suction will more than make up for the added under-water resistance.

The lower unit consists of a gearcase and a drive-shaft casing connecting the former to the engine. The drive-shaft casing contains the drive-shaft which is squared or splined to the crankshaft at the top and the pinion shaft at the bottom and floats between the two with no bearings in the casing. The casing also contains the tubes for the cooling water coming from the gearcase casting and in some of the 1930 models it also contains the exhaust tube for the under-water exhaust. The gearcase is a stream-line casting containing the pinion shaft and the propeller shaft with its gearing, the pump or scoops for the circulating water and the outlet for the under-water exhaust. The gearing usually employed is a pair of straight-cut hardened-steel bevel-gears of approximately 8 or 10 pitch and very accurately ground. The gear ratio varies with different engines, but the average is about 12 to 21. Both the pinion and propeller shafts run on ball bearings in the larger models, while in the

smaller ones, bronze bushings are the usual practice. The gearcase is also usually fitted with a thin horizontal plate, known as an anticavitation plate, which is located between the top of the propeller and the surface of the water and is designed to keep the propeller from sucking in air from the surface. It permits the propeller to be run very much nearer the surface than would otherwise be possible and therefore reduces the wetted area and consequently the resistance of the lower unit. In most of the high-speed models the cooling water is circulated by a pressure-vacuum system. This consists of an intake scoop located directly behind the propeller into which the water is forced by the action of the propeller and is circulated from there through the water tubes to the jackets on the engine. From these it is returned to an outlet directly in front of the propeller on which the latter exerts a suction, thereby increasing the velocity in the circulating water. On many of the larger racing engines the velocity of the water entering the intake scoop is so great that no under-water outlet is necessary and the cooling water passes directly from the cylinder jackets, either overboard or into the underwater exhaust.

The propellers vary greatly; in general, however, three-blade propellers are used on the slow-speed or service engines, while for racing, two-blades are always used. These have a streamline hub to blend in with the shape of the gear casing, but other than this, their shape and size will vary with almost every engine. One propeller, however, is worth mentioning, in which the hub is hollow and cored passages extend out through the axis of the blades, openings to these passages being placed on the leading face in a position such that they are in the negative pressure-area when the propeller is turning at high speed. These passages are connected to the cooling-water system and form a very effective water-pump, the negative pressure as well as the centrifugal force giving high velocity to the water system. All propellers are driven by a small pin instead of a key. This pin is the weakest point in the drive line and will shear off if the propeller hits an obstruction and thus protect the rest of the engine from damage.

Two manufacturers have developed four-cylinder engines to meet the demand of the larger classes. One of these has a 40 and the other a 50-cu. in. piston displacement, but neither of them has any special features worthy of mention, as they are merely two of the two-cycle opposed-type units set one above the other. Last year considerable difficulty was experienced with the distribution of the incoming gases in these engines, obtaining the full power from the lower pair of cylinders seemed to be very difficult; also, the oil had a tendency to settle into these lower cylinders, causing considerable spark-plug fouling.

Up to the present only two four-cycle engines, one a three-cylinder and the other a five-cylinder radial, have been developed in this Country. I have been unable to get any detailed information on either of these, as very few of them have been built and they do not yet seem to be entirely satisfactory, although the manufacturer's claims would indicate that they should be highly successful after they become more thoroughly perfected.

Standardization of Parts and Dimensions Urged

I believe that this covers most of the features of the outboard engine that are of interest, but I would like to say a few words here about standardization of the different makes and sizes. Up to now no evidence of cooperation between the various manufacturers has been found and the owner of a motorboat has to make a number of changes in his hull if he wishes to change from one engine to another. This is particularly objectionable in the racing field where a driver is forced to either carry several boats with him or make changes on his boat between races so that he may enter the various events with different engines. If a few of the more important parts that fit on to the boat were standardized, this would not in any way interfere with the efficiency or performance of any of the engines.

For instance, at present different engines have various lengths of driveshaft which means that a stern of a particular height must be built on the boat for each individual engine-model. If the manufacturers could agree on one height it would greatly simplify the task of the boat builder as well as the owner and driver. This also holds true of the angle at which the stern is set. All the engines are adjustable for a slight variation in angle, but if the maximum or minimum of this adjustment were standardized, blocking out the transom to fit an engine as had to be done in a number of cases last year would be unnecessary. All engines are fastened to the boats by some form of clamp which I believe is different in almost every make and model on the market, although the whole device could very easily be designed so that it would conform to some standard size. The throttle is usually controlled by a bowdoin wire, but it does not always come off from the same side of the engine and the fittings holding the wire are seldom the same. The attachments for the steering cables are also an important item, although different drivers prefer various ways of connecting their steering gear; if the attaching rings on all engines were of the same size and in exactly the same location, this would be very much easier.

We will hope that some time in the future the manufacturers will get together and establish a standard for these details, as it would be a great help not only to the industry but also to the buying public.

THE DISCUSSION

H. H. Brown[2]:—I think that the relative speeds of the propeller and engine should receive considerably more attention. On a fairly large cruiser that I have I changed the engine and the original 18-14 propeller with a reduction gear for a 20-16 propeller. The latter is only a very little larger in diameter, and the average person could not tell the difference, but I reduced the slip at my regular cruising speed from about 33 to 25 per cent and the fuel consumption from 2¾ to 1¾ gal. per hr. On all outboard engines we have some speed reduction between the engine and the propeller. We must have a gear anyhow, and I have always felt that we could get very much more efficiency on the present outboard engine if we would use a greater reduction

[2] M.S.A.E.—Red Bank, N. J.

and a somewhat larger-diameter screw, possibly increasing the pitch.

On the matter of standardization, I fully agree with Mr. Dunnell. When purchasing parts of various outboard engines for a friend of mine recently, I was really surprised to find that the various little parts, which could just as well be standardized on a new model, were not. They are made just enough larger so that you cannot use last year's parts on this year's model. This is another thing that the makers themselves should standardize, I believe, as they not only would save the owner and operator and repairman but also themselves.

Reasons against Large Gear-Reductions

JACOB DUNNELL:—A larger gear-reduction is not used for two fairly sound reasons. Of course, the service engine has a greater reduction in it, in most cases, than the racing type. However, if we put in a still larger reduction, we will, in the first place, make the whole lower unit of our engine larger and therefore heavier, and they are pretty heavy now. More important is the fact that a large slow-speed propeller cavitates much worse than a smaller high-speed one when placed as near the surface as in an outboard. In our inboard power boats the propeller is far under the bottom of the boat where it cannot suck the air in. If we try to reduce the gear ratio very much in an outboard engine the large propeller must have a very large cavitation plate over it, so that it would not suck the air down into the propeller.

LEONARD OCHTMAN, JR.[3]:—Standardization of outboard engines is a subject that the Motorboat Division of the S.A.E. Standards Committee has had up very recently. A committee is being formed of representatives from each of the outboard-engine builders, and we expect that during the coming year some progress will be made in that direction. That, of course, will be a little too late to affect this year's production, but very possibly the outboard engines that we will see a year from now will have very similar mounting-dimensions.

JAMES CRAIG[4]:—While outboard-engine builders do not make very many small sizes, they are able to obtain very low weights. To me that is very impressive. The internal-combustion engine has apparently the inherent property of being equally efficient regardless of what size we make it, and we can almost state that it is equally efficient in weight regardless of the size. That a little outboard engine with all the contrivances that are incorporated in it in connection with power cylinders and the extension reaching down to the gearbox can be built with a weight of 2 lb. per hp. is very commendable.

Larger Propeller Gives Increased Efficiency

A. E. LUDERS[5]:—The comment about the larger propeller-wheel giving increased efficiency under certain conditions seems to me to carry weight. Usually we would get better efficiency on the heavier-duty outboard-engines if we could use larger propeller-wheels. If trouble is experienced with cavitation the remedy is simple; increase the propeller diameter. On speed boats with propellers making over 1200 r.p.m. we meet the cavitation problem that invariably occurs by increasing the propeller diameter. In other words, a propeller that is figured theoretically to give the necessary thrust to absorb the available horsepower when making 1200 r.p.m. or over will speed up and cavitate and we must increase the diameter to a size that would theoretically give 20, 25 or 30 per cent more thrust than is apparently required. An extreme case is the surface propeller that is, however, out of water and which by increasing the diameter about 50 per cent over the submerged type of wheel will give the necessary thrust in spite of the very evident cavitation.

MR. BROWN:—Another way, not any better perhaps than Mr. Luders suggests, would be simply to put the propeller down lower in the water. I have had a boat and by simply cutting down the stern about 1½ in. I have raised the speed 3 sec. per mile, with no other changes. This is another way to overcome cavitation or any trouble that you might have. Proper reduction gearing will, I believe, give very surprising efficiency if the average maker would make the experiment.

[3] M.S.A.E.—Chief engineer, Elco Works of the Electric Boat Co., Bayonne, N. J.

[4] Advisory engineer to the Technical Committee, National Association of Engine and Boat Manufacturers, New York City.

[5] President, Luders Marine Construction Co., Stamford, Conn.

Combustion-Chambers, Injection Pumps and Spray Valves

(Concluded from p. 600)

methods of combustion described in this paper can be used for stationary engines, as such engines usually have a limited range of speed. Injecting the fuel directly into the combustion space is the system that has been used almost exclusively for engines having high output.

Solid-injection automotive oil-engines for land, water or air propulsion present somewhat different problems. Engines for service such as in small motorboats, motortrucks, motorcoaches and tractors can be made to operate most easily at various speeds with a smokeless exhaust if designed with a precombustion-chamber or auxiliary air-chamber. Direct injection, with suitable provision for turbulence, finds its best application in engines of higher output, such as are required for locomotives and marine engines. Aviation engines, in which much interest is now being shown, are likely to use whatever system will give the highest output over a long period with the utmost in safety of operation, light weight and low fuel-consumption.

Automotive Research

Design of the Silver Bullet

Original Engineering Solutions of Many Special Problems Revealed by Designer Coatalen

THE Silver Bullet was designed and built from its inception to beat the world's straightaway mile record for speed on land. Louis Coatalen, the Sunbeam Motor Car Co.'s managing director and chief engineer, who has planned many successful racing car jobs, virtually made this car to fit the driver. A silhouette of Kaye Don, who was to drive it, was projected against a wall and the car was designed so that its profile would fit within the projected area, the width of Mr. Don's shoulders determining the angle of the V-type engine. This is only one of the many unique design features which show a disregard for precedent and a noteworthy pioneer effort in the development of a high-speed vehicle. The details of design and construction, as explained by Mr. Coatalen at a recent meeting of the Metropolitan Section of the Society, are regarded as of sufficient technical interest to warrant publication in this section of the S. A. E. JOURNAL.

The General Layout

This bullet-like 24-cylinder 5-ton automobile was built theoretically to do 280 m.p.h. It has a width of only 30 in., which is amazingly small for a vehicle having a wheelbase of 15 ft. 5 in. and an over-all length of 30 ft. The car is virtually filled with mechanism, as shown in Fig. 1. The front wheels are set back about 6 ft. from the nose, and the rear wheels are placed about 9 ft. from the tail, with the driver's seat just in front of them.

The deep frame tapers toward the rear so as to permit the rear springs to be located on top of the frame members and is very substantial, with exceptionally strong cross-members. The whole car is sheathed in silvered aluminum.

Particular attention has been given to the safety of the driver. Two hoops made of special steel, strongly reinforced, have been placed just back of the engine to protect the driver in case the car should turn over. With lighter racing cars incorporating this safety feature, the driver has been able to save himself in cases of overturning simply by withdrawing his head quickly inside the car. The windshield consists of three triangular sheets of nonshatterable glass set in nickel-steel supports.

Double 12-Cylinder Engine Design

The powerplant occupies most of the space between the front and rear axles. There are two V-12 engines, or, to be more exact, two separate units that operate as one engine, the water and oil-pumps for both sections being driven by the forward engine or unit and the supercharger for both being attached to the rear unit (see Figs 2, 3 and 4). As there is very little space between the two engines, the centrifugal supercharger and carbureters, which are of enormous size, were placed at the ends of the engines.

Each engine weighs less than 1000 lb., and, with a 5½-in. bore and 5⅛-in. stroke, the total displacement of the 24 cylinders is 2922 cu. in. The unusual cylinder proportions, the stroke being less than the bore, and a 50-deg. angle for the V were necessitated to keep within the small frontal area initially determined upon.

Constant variation occurs in the compression ratio of the

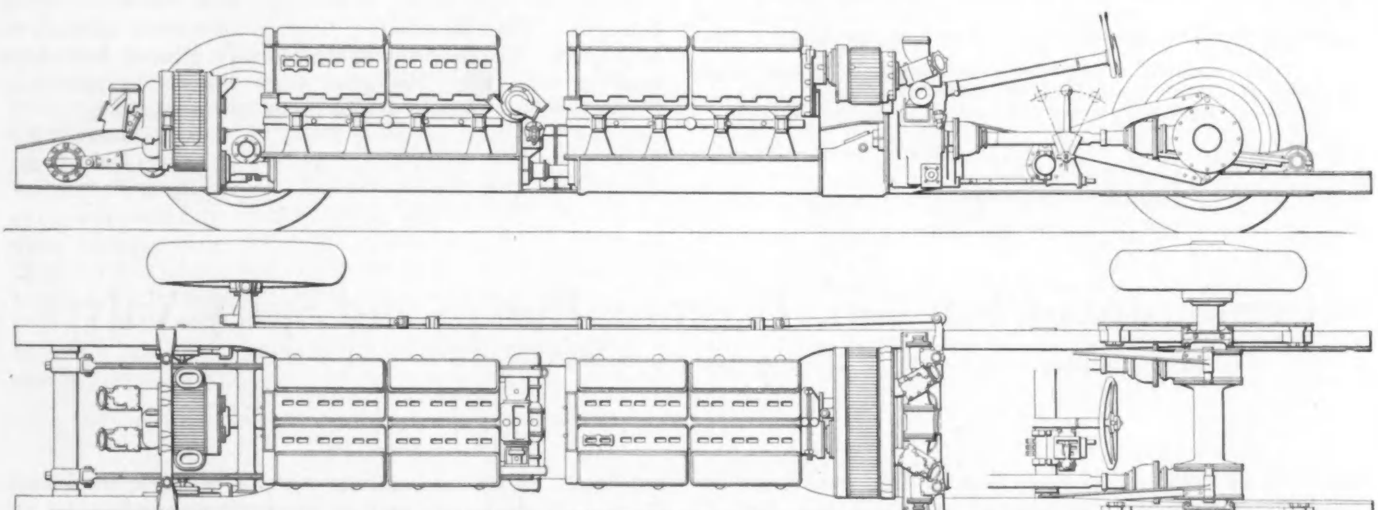


FIG. 1—GENERAL ASSEMBLY OF THE SILVER BULLET RACING CAR

Note the Massive Frame through Which the Front Axle Extends and Is Connected Thereto by Means of Radius-Rods. The Frame Extends below the Rear Axle. Drive and Torque Reaction Are Taken by a U-Shaped Radius-Rod. An Independent Propeller-Shaft for Each Rear Wheel Extends from the Transmission. Each Front Wheel Is Independently Controlled by Jointed Side-Rods. The Forward Supercharger Has Been Replaced by a Single Supercharger for Both Engines Placed at the Back of the Rear Unit and the Forward Space Is Taken up by the Ice-Cooling-Tank

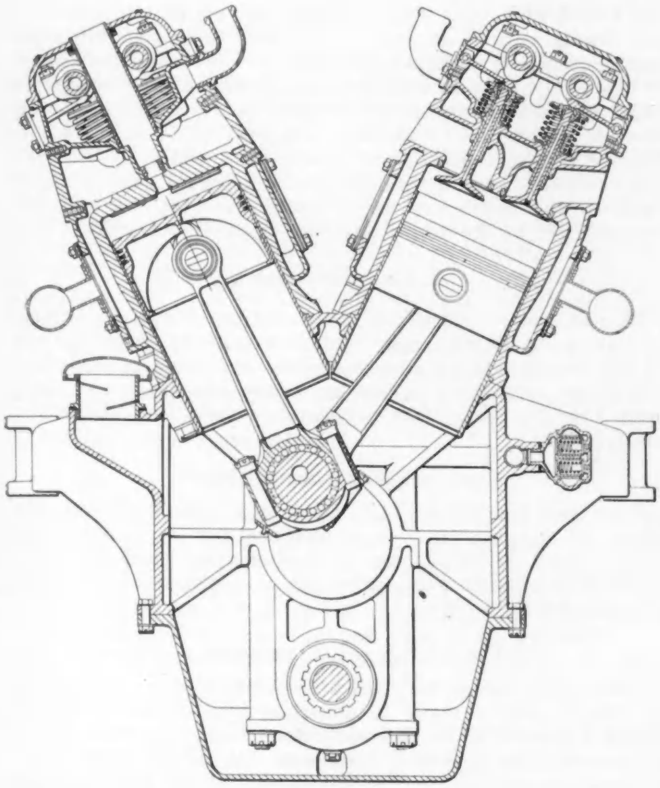


FIG. 2—CROSS-SECTION THROUGH ONE OF THE ENGINES
The Angle of the V Is 50 Deg. Each Cylinder Has Four Valves with Stems Drilled Hollow for Lightness and Fitted with Double Concentric Springs and a Slipper between the Cam and Valve to Take Side Thrust. The Cylinders Are Aluminum-Alloy Castings with Pressed-in Nitrided Steel Liners and Shrunk-in Valve-Seats. Note that the Spark-Plug Is Centrally Located above the Combustion-Chamber: also the Connecting-Rod Big-End Roller-Bearing on the Case-Hardened Crankpin

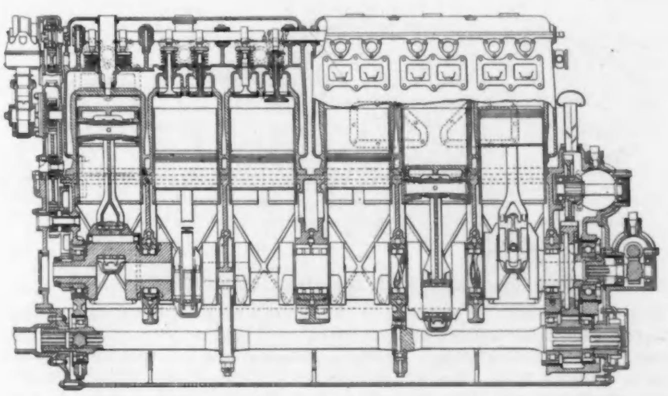


FIG. 3—LONGITUDINAL SECTION THROUGH FORWARD ENGINE
The Water-Pump and Oil-Pump Drives Are at the Rear. The Crankshaft Drives a Lay Shaft below It through Spur Gears, with a 30:13 Ratio. The Forked Connecting-Rod Bears Directly on the Crankpin, with a Roller-Bearing in Each Fork, Straddling the Opposite-Cylinder Connecting-Rod Which also Has Two Roller-Bearings. The Main Bearings Are also Split-Type Roller-Bearings. The Overhead Camshaft Is Driven by a Gear Train at the Forward End

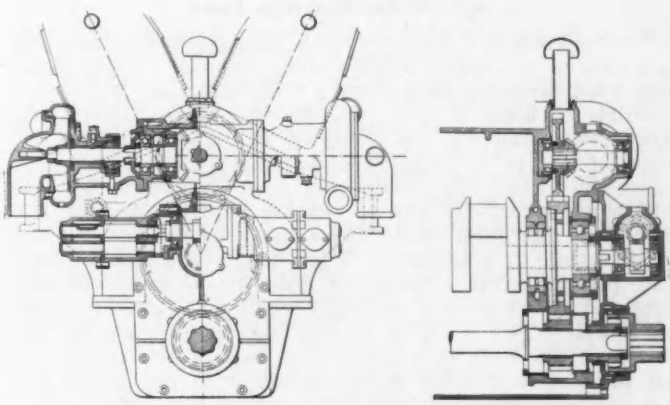
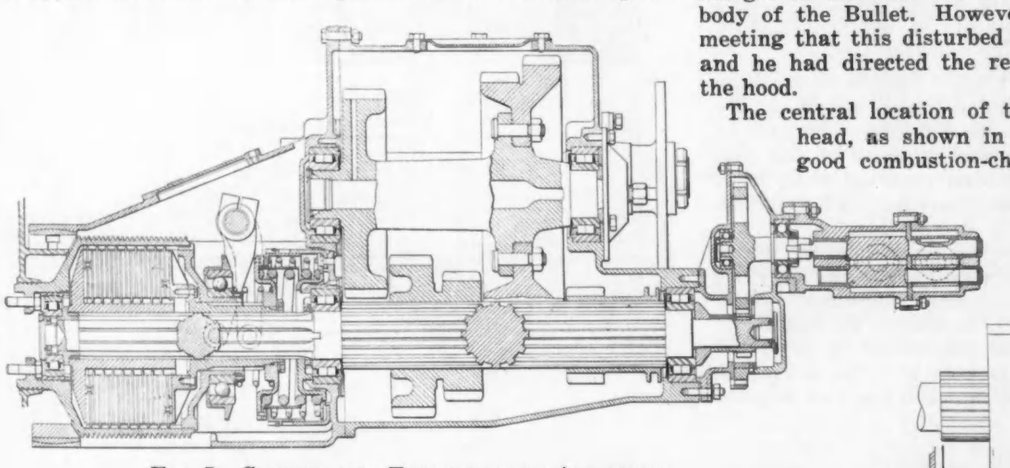


FIG. 4—REAR END OF THE FORWARD ENGINE
This Shows the Water and Oil-Pump Drives, the Gear Connection between the Crank and Lay Shafts and the Spherical Coupling between the Lay Shafts of the Two Engines

engines, which have an unsupercharged ratio of 5.6:1. A centrifugal fan running at 20,000 r.p.m., is used for supercharging and produces a variation in pressure according to the speed of the car. In previous Sunbeam racing cars the inlet of the carbureter has been in still air within the body, but to obtain additional pressure of air for the supercharger in this case the air-intake was placed outside the body of the Bullet. However, Mr. Coatalen stated at the meeting that this disturbed the action of the supercharger and he had directed the replacement of the intake under the hood.

The central location of the spark-plug in the cylinder-head, as shown in Fig. 2, makes possible a very good combustion-chamber design from the standpoint of avoiding detonation and giving increased efficiency. The end of the plug does not actually extend into the com-



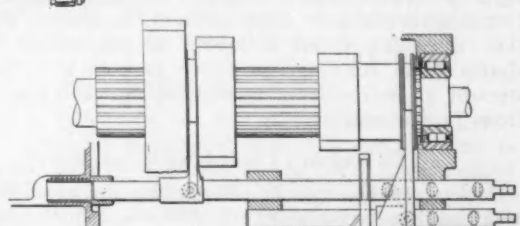


FIG. 5—CLUTCH AND TRANSMISSION ASSEMBLY
Three Speeds Forward Are Provided and the Friction Clutch Is Supplemented by a Positive Clutch Which Later Comes into Action. Roller-Bearings Are Used Throughout Except for the Clutch Throw-out Bearing. Due to High Speed of Rotation, Dry-Sump-Type Oil Circulation Is Maintained Similar to Engine Lubrication. The Double Oil-Pump for This Purpose Is Seen at the Rear End of the Transmission. The Ratio between the Clutch Shaft and Propeller-Shafts Is 23 to 20

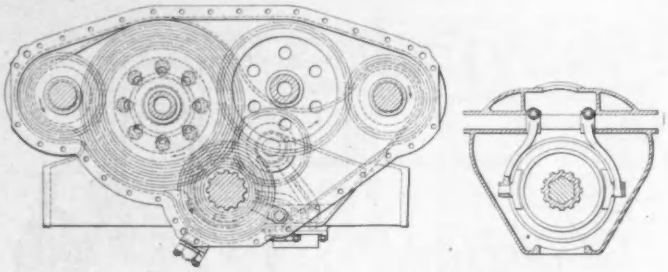


FIG. 6—REAR END OF THE TRANSMISSION

The Clutch Shaft Is below and the Countershaft above and to the Left. Shafts at Each Side, Rotating in Opposite Directions, Drive the Rear Wheels through Propeller-Shafts, and an Idle Gear Conveys Power from the Countershaft to the Right-Hand Shaft. Clutch Throw-out, Pressure Plate and Positive-Clutch Splines Are Shown in the Drawing at the Right

bustion-chamber but the ignition flame issues through a port of relatively small diameter. This effectively prevents oiling-up of the plug.

There are two distributors per engine, each of which serves a bank of six cylinders.

Split Roller-Bearings Used

The engines are equipped with split roller-bearings and are said to be capable of developing 4000 hp. Roller-bearing manufacturers have always contended that it was impossible to make a split roller-bearing work successfully, but notwithstanding, the Sunbeam Motor Car Co. has developed a type of split roller-bearing which it has used most successfully in racing cars since 1921. The big-end of the connecting-rod and its cap are hardened and ground and form the outer race. These bearings are not difficult to dismantle or reassemble. When taken out, they go back into position again without any difficulty, being guided and centered by the ground rod bolts, which are carefully fitted as dowels. This solution of the bearing problem is followed in the main bearings of the engines and eliminates all lubrication trouble in connection with connecting-rod big-ends and main bearings. It is perhaps one of the most interesting features of the engine, since it has never before been attempted in an engine of this size. The case-hardened crankpins are 60 mm. in diameter and the rollers are ¼ in. in diameter and ¼ in. long.

Two sets of rollers are used in each connecting-rod big-end. The cylinders on each side of the V, and therefore the connecting-rods, are in line, one connecting-rod straddling the other and bearing directly on the pin, with a roller-bearing in each fork member.

A new type of nitrided steel that compares in hardness with glass is used for the cylinder liners, to which Mr. Coatalen attributed the fact that no difficulty with pistons, liners or rings has been experienced in spite of the high piston-speeds. In fact, Mr. Coatalen reported that, after 40,000 miles on numerous engines, the emery wheel grinding-marks in the cylinder bore are still visible.

Connection between the two engines is effected by means of a flexible telescopic joint fitted with splines and provided with a large-diameter slightly-spherical dog-wheel or internal-external gear arrangement, as shown in Fig. 3. If that were not fitted it would be impossible to keep the shafts from binding, as there is bound to be a certain amount of independent movement between the two engines from frame weave.

Engines Cooled with Ice Water

Cooling of the car is effected by ice carried in a large tank having a capacity of 750 lb., which is ample for running the car at full power for 5 min. This is a considerably longer period than is required to break the record. The course is about 8 miles long, and, assuming the average speed of the car is approximately 120 m.p.h. throughout the entire run, only 4 min. would be required to complete the course, only 30 sec. of which would be at the full-power maximum-speed condition necessary for breaking the record.

Probably no liquid readily available has a greater specific heat than water, and starting with ice gives the maximum cooling range. Mr. Coatalen said that little is known in Europe concerning ethylene glycol. The water in the cooling system is passed into the ice-tank jacket and bypassed back to the engine so as to avoid lowering too far the temperature of the water entering the cylinder-jacket.

Engine Lubrication

The oil-pumps, of which there are two for each engine, operating on the dry-sump system, are driven from the end of the crankshaft by means of spur and skew gears, while the water-pumps are driven by means of a spur and bevel gear (see Fig. 4). Pure castor-oil is used for lubricating the engine.

Fuel an Alcohol-Benzol Blend

The fuel for the Silver Bullet was selected with the object of keeping as low a temperature as possible. It consists of a 50-50 mixture of alcohol and benzol, with the addition of about 3 per cent of ether to give a wider range of explosive mixture.

The Clutch and Transmission

The clutch, which revolves at a much higher speed than the crankshaft, is made to absorb only about 40 per cent of the engine torque, the remainder being absorbed by a positive lock in the clutch somewhat like an internal-external gear engagement. The serrations in the clutch drum drive one set of discs and also receive the locking member.

The transmission provides three forward speeds and a reverse speed, and has no direct drive (see Figs. 5, 6 and 7). All gears are indirect. The clutch and transmission housing, which serves as part of the frame, is connected to the engine casing by means of a spherical joint to allow for a certain amount of movement between the rear engine and the transmission.

The power is transmitted to the rear axle by two propeller-shafts turning in opposite directions. By this means

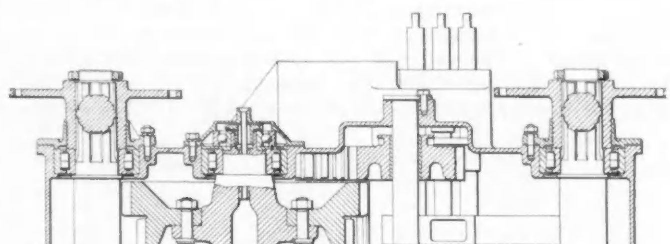


FIG. 7—SECTION THROUGH UPPER TRANSMISSION SHAFTS

Gears on the Clutch Shaft Are Below. The Reverse Gear and Idler Are Clearly Shown

the torque reaction is balanced so that the car remains level when the clutch is engaged.

At the speeds involved, it was found practically impossible to secure standard roller-bearings which would stand up. The rollers of standard bearings are so heavy and have such large diameter that oil-churning alone, independent of other forces acting, destroys such bearings in a very short time. This situation was met through the cooperation of a ball-bearing manufacturer in the designing of a special type of roller-bearing having very small rollers operating in double rows. These special split roller-bearings are fitted to all the main shafts, including the rear axle and transmission. They are all specially selected and fitted with specially designed duralumin cages built for this car. An idea of the magnitude of this undertaking is given by the fact that more than 300 bearings of this type, none of which are standard products, are employed in the car.

Castrol, a mineral oil containing castor-oil, is the lubricant used in the transmission.

Double-Drive Rear Axle

There is no differential on the car, nor are the usual rear-axle shafts used. The rear universal-joint of each propeller-shaft is connected to a companion flange that drives the bevel-gear pinion through a short spline-shaft made integral with the pinion, as shown in Fig. 8. The bevel pinion drives the ring gear, which is mounted on a short hollow-stub live axle, which in turn drives the rear wheel. The wheel is supported by roller-bearings on a fixed forged-steel axle-housing.

The rear axle is so constructed that it can be dropped easily and quickly to enable the final gear ratio to be changed with minimum difficulty.

Large torque-arms take care of the torque and reaction of the rear wheels. Spring shackles are eliminated, the ends of the springs being fitted into slots in cylindrical bushings carried by frame brackets, the arrangement allowing freedom of motion of the springs through the bushings so that the springs are not affected by either torque or drive reaction but act as weight-carrying members only without being subjected to any other stresses.

Wheels Steered Independently

An independent steering-mechanism, provided for each wheel to prevent two wheels from vibrating in synchronism, thus eliminating the possibility of induced shimmy, is another important safety factor employed.

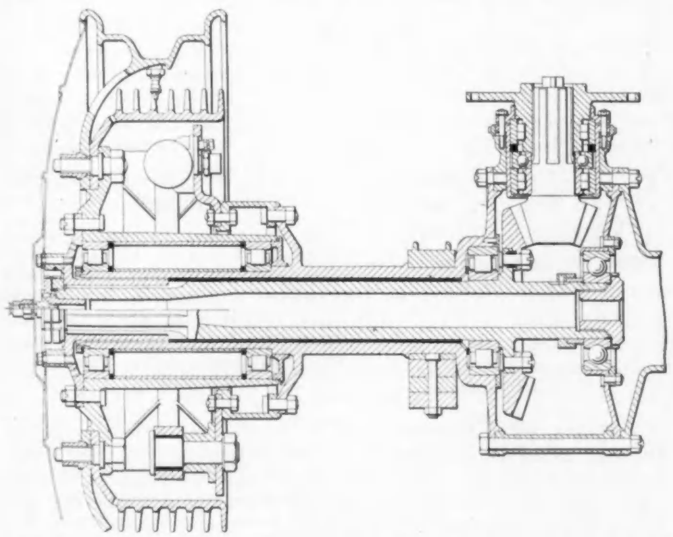


FIG. 8—HORIZONTAL SECTION THROUGH BUILT-UP REAR AXLE, DIFFERENTIAL AND WHEEL HUB

Less than One-Half of the Axle Is Shown. The One Large Ball-Bearing Takes the Thrust of the Bevel Gear and Wheel. The 12:33 Gear-Ratio Gives an Over-All Ratio between Engine and Wheel of 1.04:1. The Wheels Are of Steel and Incorporate Integral Drop-Center Rims

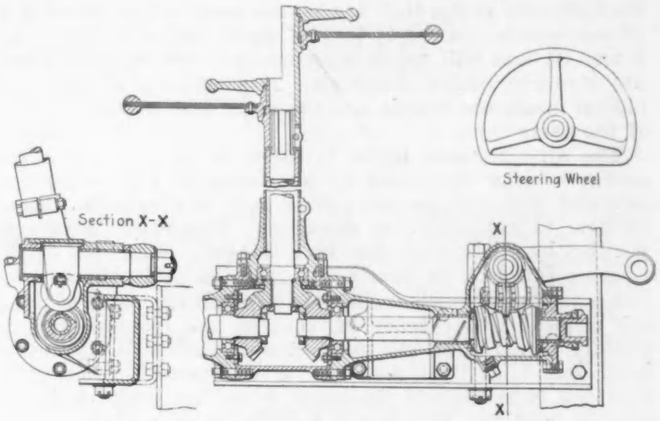


FIG. 9—STEERING-GEAR ASSEMBLY

Note the Irregular Shape of the Steering-Wheel To Give Leg Clearance. The Driver Must Remove the Wheel To Get Out of the Car. The Drawing Indicates Two Trial Column-Lengths. The Wheel Fits the Column on Splines and Is Held in Place by a Nut with Locking Taper. The Steering-Shaft Gear Meshes with Two Bevels, One at Either Side, and a Marles-Type Steering-Head Is Incorporated at Each Side

The shaft of the steering column carries a bevel gear, as shown in Fig. 9, that meshes with two bevel gears mounted on horizontal shafts extending respectively to the right and left. These shafts operate two steering-gears, one mounted by the right and the other by the left frame-member. The crank-arm of each steering-gear actuates a long push-rod extending independently forward and through five guide bearings to the steering-knuckle arm on the front wheel on the corresponding side of the car. The push-rod is made up in several sections, universally jointed together. The housing for the steering-gear mechanism is a very rigid member extending crosswise of the frame, in which position it serves as an auxiliary frame-member.

It was found necessary to employ in the construction of the steering parts a special type of steel that would withstand the terrific stresses incident to the high speeds and great weight combined with the gyroscopic action of the wheels.

Front Axle Slides on Springs

The front axle, shown in Fig. 10, is of the built-up type and is not affixed to the car by a spring, since, as in the case of the rear suspension, the spring is employed only as a means of supporting the vertical load and can slide slightly in a fore and aft direction. The front axle is maintained in position by two radius-rods, one on either side very near to the bottom. A rubber pad acts as a bumper.

Silk-Thread Plain-Tread Tires

The tires used are the only safe ones with which to travel on the beach, the cords being made of silk thread and plain treads being used. With any extra thickness of rubber, the centrifugal load would throw the treads off immediately, so only a film of rubber can be used over the carcass.

Air and Hydraulic Brakes

The braking is hydraulic, but the initial part of the braking is done by an air-resistance brake or drag which is fixed between the two vertical fins on the car. This method of braking was adopted because it seemed dangerous to employ a mechanical brake when the car is going at a rate of 300 m.p.h. The air brake has the safe effect of steadying the car. In any case, the car will straighten its course completely under the influence of the air brake and fins.

To avoid extra air-resistance due to the brake-drums for

the hydraulic brake, they are housed inside of special wheels. These wheels are built in one piece, as shown in Figs. 8 and 10, and will rotate at more than 300 m.p.h. without any stress or undue distortion. The brakes are completely hidden inside the wheels and the front and rear brakes are of the same type.

The air-resistance brake is fitted on a tube, the brake surfaces being supported by a number of ribs which are provided with springs and rubber pads to absorb the shocks incident to application of the brake. This brake is held in position by a lock controlled by a trigger. When the driver releases this lock by means of a Bowden cable, the springs begin to give a small inclination or rotation. As the braking element is not balanced, that is, the front portion is slightly larger than the rear, it will automatically rotate itself into a vertical position. A counteracting spring is provided to withstand the shock when the brake is in its applied position. This is not a brake in an ordinary sense because, once it is on, the driver cannot release it without stopping the car and resetting it.

A great advantage of this brake, apart from the fact

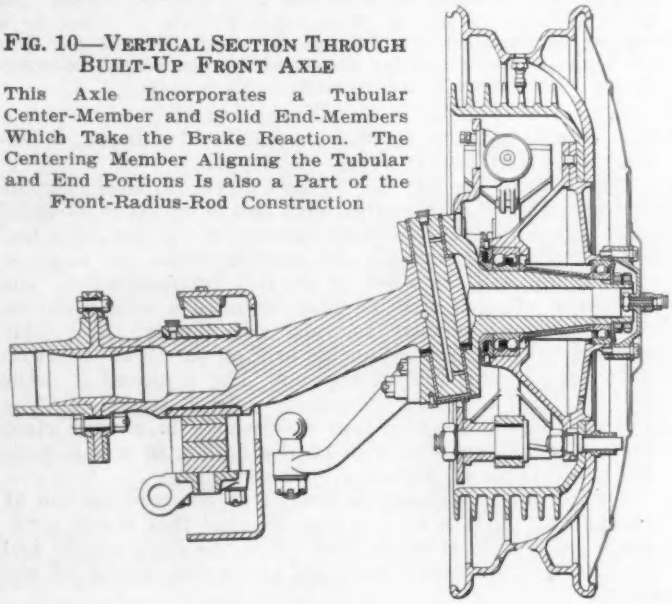


FIG. 10—VERTICAL SECTION THROUGH BUILT-UP FRONT AXLE

This Axle Incorporates a Tubular Center-Member and Solid End-Members Which Take the Brake Reaction. The Centering Member Aligning the Tubular and End Portions Is also a Part of the Front-Radius-Rod Construction

that there is no danger of melting the brake shoes at high speed, is that it overcomes the usual tendency to transfer the weight of the car from the rear wheels to the front wheels when the brakes are applied at a very high speed. When this air brake takes effect at the back, the reaction tends to lift the front of the car and counterbalances the normal wheel-braking effect. As the car is an almost perfectly streamlined body, the center of drag in stopping would, without the air brake, be very near the center of gravity of the car. The further the center of drag is behind the center of gravity, the greater is the resulting stabilizing moment. There is, therefore, the additional advantage that when this air-resistance brake is applied the center of drag is brought well back of the center of gravity, resulting in a large stabilizing factor which enables the driver to straighten the car perfectly in case a tendency to skid is developed.

Testing and Streamlining

It is the custom of the Sunbeam Motor Car Co., when building special racing cars, to test on the bench not only the engines but, as far as possible, all the parts. The Silver Bullet was completely tested, except for the springing, as it would be tested on the road.

The wind-resistance tests were checked thoroughly. Data on all other racing cars have practically agreed within 2 or 3 per cent with the wind-tunnel figures, Mr. Coatalen reported. The wind resistance on the Silver Bullet proved

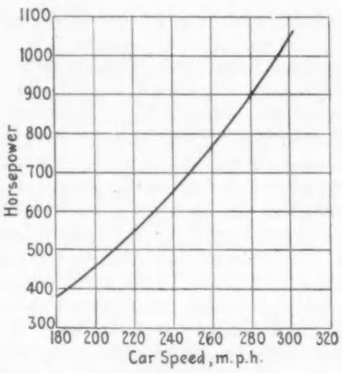


FIG. 11—COMBINED WHEEL AND TRACTIVE RESISTANCE

Shows Horsepower Required To Drive the Silver Bullet at Various Speeds. Data for Wind Resistance Obtained from Wind-Tunnel Tests

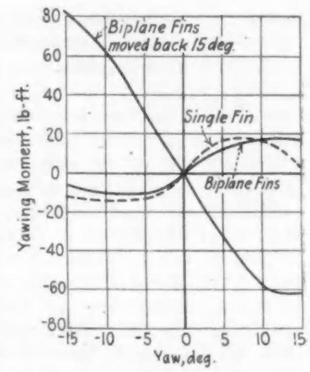


FIG. 12—YAWING MOMENT OF VERTICAL TAIL-FINS SHOWN IN LB-FT. AT A SPEED OF 300 M.P.H.

to be less than 50 per cent of that of its nearest competitor, although there is not a great difference between the cross-sections of the two cars. This is due to the fact that the interference between the wheels and the body has been reduced to a minimum.

The yawing-moment tests were made by placing the car slightly askew in the wind-tunnel. At first the car was tested with a single monoplane fin, and, as shown in Fig. 12, there was a very slight stabilizing moment which reached a maximum at about 8 or 9 deg. and decreased rapidly. A small amount of stabilizing effect is desirable to enable the driver to correct the direction, so the monoplane fin was abandoned and a biplane fin substituted. The latter arrangement produced a curve which, except for the lack of the drop, is more or less of the same shape. These two fins were moved back 15 in., which is very little in respect to the length of the car, but a complete change in the shape of the stabilizing curve was produced.

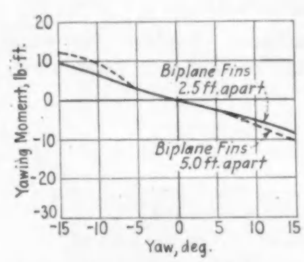


FIG. 13—YAWING MOMENT AT TWO SPACINGS OF THE VERTICAL TAIL-FINS

Shown in Lb-Ft. at a Speed of 300 M.P.H.

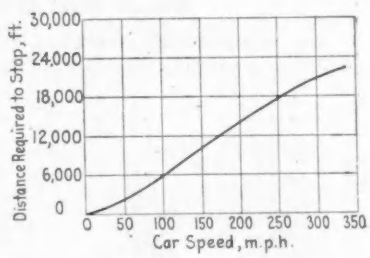


FIG. 14—EFFECT OF THE AIR BRAKE

The Horizontal Tail-Fin Acts as a Brake When in Vertical Position and the Curve Shows the Distance Required To Stop When thus Utilizing Wind Resistance, Both Wind and Increased Tractive Resistance Being Taken into Account

Further tests showed that, with the air brake applied, the car could be stopped from 300 m.p.h. in less than 7000 yards without any assistance from the mechanical brakes (see Fig. 14). The same stopping distance without the air brake would be about 9000 yards.

The unique method of determining the frontal area of the car and of fitting the car to the driver, the remarkable engine built in two separate units yet operating as one engine, the special roller-bearings, ice cooling, air-resistance braking, and streamlining unite to make this car one of the year's outstanding accomplishments in creative design.

Production Engineering

Saving Material with New Tools

Tungsten Carbide Makes It Possible to Reduce Finish Allowance—Applications Discussed

WHAT is suggested as the major saving that can be effected by the use of tungsten-carbide tools was stated by A. K. Brumbaugh, of the White Motor Co., at the Production Session of the Annual Meeting. With labor only 10 per cent and material 70 per cent of the production cost of a vehicle, he pointed to the fact that a relatively small economy in material might result in a greater saving than a major cut in labor cost. Such a saving can be made in the cost of castings and forgings, he believes, by the use of tungsten-carbide tools, which will cut through scale and sand. Mr. Brumbaugh intended his brief paper as a spark-plug to start discussion on tungsten-carbide tools. This discussion is printed herewith, beginning with Mr. Brumbaugh's contribution.

Brumbaugh Points to Savings

Manufacturing engineers have the job of reducing raw materials to a finished product. This is a job that involves materials, machinery and men. We may think that the materials are handed to us by the design engineers and that our chief problems have to do with the economies in labor and in machinery.

Of the total cost of a motor-truck, ready to ship, about 10 per cent represents labor, 20 per cent is overhead and 70 per cent is material. Have we not been devoting too much of our attention to the 10-per cent item and not enough to the 70 per cent?

Considerable attention was given, at a recent Production Meeting, to the problem of handling chips. Our capacity for producing chips is being increased constantly by the production of more rugged machine-tools and of cutting-tools that will operate with higher speeds or heavier cuts. All of this work is being done to destroy something of value. That portion of the raw material which is converted into chips costs as much per pound as the part which enters into the finished product.

Limitations of forging and casting processes sometimes make it necessary to remove large amounts of metals, but still there are many cases in which it is possible to reduce the amount of material to be removed in finishing the rough part. The accomplishment of new machines and new cutting-tools usually is expressed in time saved. Since the relationship of material cost to labor cost is approximately 7:1, might it not be more profitable to concentrate on saving material?

Reducing the Waste of Materials

Such a saving can be effected by reducing the finish allowance on castings and forgings, but the obstacles to be overcome in doing this were too great, varied and powerful until recently. We have been obliged to allow ample finish on castings to permit a tool to cut under the scale, and die wear has been an important factor in the finish allowance for forgings. The problems of scale, sand inclusions and hard spots on the surface are difficult to meet. Some of them have been overcome by surface grinding, with consequent uncertainty in locating-points and the necessity for increased tolerances for later operations. If grinding was not practicable, the last resort has been to worry through as best we could, with frequent grindings of tools and the possibility of scrapping the part after much labor has been spent upon it.

Tungsten-carbide and similar tools offer a possibility of clearing up many of these difficulties. Such tools are virtually unaffected by scale or slag, and will produce a commercially true finished surface on a rough part, within its limitations, in a single cut.

To take full advantage of the possibilities of these tools, we must have the earnest cooperation of foundry and forge men in improving their processes, so that we can secure uniform castings and forgings, having the minimum finish allowance that is sufficient to produce cleanly finished parts.

Finished parts weigh probably 12 per cent less than rough castings, including the loss entailed in scrapping partially finished parts. If we could reduce that loss to 6 per cent, that would be equivalent to a real saving of about 40 per cent of the labor cost.

Hudson Success Is Qualified

Following Mr. Brumbaugh's remarks, Chairman L. V. Cram called on S. Wilson, of the Hudson Motor Car Co., for his experience with tungsten-carbide tools. Mr. Wilson responded with the following remarks:

We began to use tungsten carbide about as early as anyone; we began to order tools of this material at a great rate, but we had such a high percentage of breakage that we found the cost to be greater than the saving. We could run individual tests showing the cutting ability of the tools, but what happened in the shop caused the department foremen, who are responsible for tool costs, to object. They would be satisfied if the tools would do what was expected of them, but believe they are not adapted to the jobs on which they were tried.

Now we are beginning to find the causes of some of our troubles and to eliminate them, so that we are using tungsten-carbide tools successfully on a number of operations. But we still have operations on which we have not been successful, because the tools have cost more than they have saved. They work for a time and then, because of poor or irregular castings or something loose on the machine, so many tools would break that the department foremen would discard the tools.

I should like to hear how other users have eliminated such troubles. We know that it is necessary to redesign the tool blocks, to use heavy machines and to run them faster than with steel tools. We have done whatever the manufacturers of the tools have recommended, but still we have trouble.

White Experience Is Promising

Howard Jones, of the White Motor Co., was asked to give definite experiences of the White company with tungsten-carbide tools. Mr. Jones spoke as follows:

When Carboloy was first introduced, its cost had some influence on the extent to which we experimented with it. Like Mr. Wilson, we found certain applications where tools of this material were unsatisfactory; we are meeting with good success in machining cast iron, bronze and aluminum, but have had no success worth mentioning with steel. We find that we can finish as many as 50,000 aluminum pistons, which have been very trublesome with other tools because of sand, without noticeable tool wear. Our method is to let one man operate three or four machines. In this way it is not necessary for us to speed up the machines to an extreme.

When we give a job to the Carboloy engineers, we keep a careful record of it. We have very good success on flywheels; clutches; malleable-iron axle-

housings; aluminum pistons; and with parts machined on diamond-boring machines, which include connecting-rods, pistons and crankcases. We have Carboloy tools in these machines that have bored as many as 15,000 crankcases, the tools being relapped six times. We find that the tungsten-carbide tools wear 25 to 50 times as long as high-speed-steel tools per grind.

We cannot arbitrarily decide that we will adopt a tungsten-carbide tool for some particular job and make a success of it. The various manufacturers of these tools have engineers who study jobs, and they will not recommend them in places where they would not work satisfactorily. I shall be glad to answer any questions in regard to time, speeds and feeds.

Questions Answered by Jones

In response to Mr. Jones' invitation, a number of questions were asked and remarks made by John Younger, of Ohio State College, M. O. Teetor, of the Perfect Circle Co., and others, as follows:

MR. YOUNGER:—Are your machining speeds with tungsten-carbide much higher than with steel?

MR. JONES:—Higher speeds than we have been using with high-speed tool-steel are possible on some of the latest machines, but we find that we cannot increase the feed proportionately with the increase in speed when using tungsten-carbide tools. We have made several applications of Carboloy in machining flywheels. We use a tool of this sort at the rim, where the cutting speed is greatest, and high-speed-steel tools on the smaller diameters. Normally the speed can be 20 or 25 per cent higher for all tools, with this arrangement than without the tungsten-carbide tool.

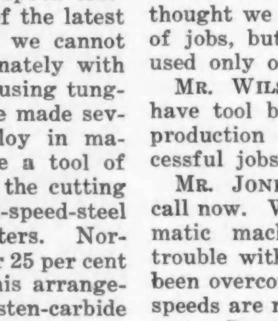
Sharpening the New Tools

MR. TEETOR:—How do you sharpen the tools?

MR. JONES:—The tools are ground with great care by a special method on a special wheel recommended by the makers of the tools. Most of them are held by hand, but tool-holders are used for grinding piston-grooving tools.

MR. TEETOR:—Have you tried shock-absorbing tool-holders, using some material such as leather or rubber?

MR. JONES:—No. We find it necessary to take very light cuts, less than 0.0002 in., and we use solid tool-holders.



MR. TEETOR: — Have you tried lapping? Do you know whether the lapping is done with a diamond lap or with a fine stone? We have tried a cast-iron wheel impregnated with diamond dust, and other things. How important is it to have tools lapped?

MR. JONES:—We have tried it, but tools that need to be lapped we now send to Detroit, where the Carboloy Co. has extensive equipment for the purpose. I think that the material is lapped in the same way as a diamond. The last experience I had with this was on grooving tools. Considerable trouble was experienced with the job, and finally we had it done by a diamond cutter.

We find lapping necessary for ring-groove tools to secure the finish that we require and the tool life that we expect. A lapped grooving-tool costs about $25.

MR. TEETOR:—Do you get the best results with small or large pieces of tungsten carbide?

MR. JONES:—All the inserts must be backed up well. We like to have the inserts as small as possible.

MR. WILSON:—Did you have a discouraging amount of breakage before you succeeded in the use of these tools?

MR. JONES:—We did have all kinds of trouble 1½ or 2 years ago. We thought we could use them on all sorts of jobs, but found that they could be used only on certain ones.

MR. WILSON:—Do you occasionally have tool breakage that eats into the production savings made on the successful jobs?

MR. JONES:—None that I can recall now. We do not use them on automatic machines. Formerly we had trouble with grooving tools, but it has been overcome. Possibly our feeds and speeds are not so high as you might expect. Some claim that the tools can be used at a cutting speed of 3000 ft. per min., but I cannot confirm that.

Making Intermittent Cuts

MR. TEETOR:—Do you use tungsten carbide for intermittent cuts?

MR. JONES:—Yes, we take an intermittent cut on pistons. The manufacturers of Carboloy use three grades of metal for their tools, but they recommend their best, which are baked and tempered, for intermittent cuts.

MR. TEETOR:—Have you made intermittent cuts in cast iron?

MR. JONES:—Yes, it is successful, but 0.005 to 0.007 in. must be ground off the tools when they need regrinding. That is more grinding than is necessary on most jobs.

MR. WILSON: — How many operations have you now for which tungsten carbide is adopted as the standard tool?

MR. JONES:—About 25 parts in all, I should say, including pistons, flywheels, brake-drums and work on the diamond-boring machines.

ALEX TAUB (Chevrolet Motor Co.):—Do you use the same speeds with Carboloy as with the diamond in boring?

MR. JONES:—We use the same. The 3-in. bore in the crankcase is cut at 1200 r.p.m., with long boring-bars. The boring machines are running at 2000 r.p.m. at the large ends of connecting-rods and 3200 r.p.m. at the small end. We are having good success with this now, but these speeds have been in operation for only about two months.

MR. TEETOR:—What clearance are you using for piston - grooving tools?

Piston Grooving and Sharp Corners

MR. JONES:—I believe that the clearance is about 0.007 in. in ½ in., ground straight. The tools are lapped on the top and all three sides. About 0.002 in. is removed in regrinding.

MR. WILSON:—Do you make both roughing and finishing cuts, and both with tungsten-carbide tools?

MR. JONES:—Yes; 0.004 in. is left in the sides of the grooves for finish.

MR. TEETOR:—Are you doing any work which requires cutting a sharp right-angle corner, for which a point must be maintained on the tool?

MR. JONES:—No; I should question the practicability of that.

MR. WILSON:—We are having great success with a job of this sort in bronze. This is an intermittent cut, with 28 slots outside, and the flange has to be finished to a depth of about 1 in., with a sharp inner corner. This is one of the jobs where we were obliged to make the tungsten carbide work because nothing else would do the job; and we have succeeded, although we have had no success on some other jobs that seemed to be simpler.

Carboloy Representative Speaks

Chairman Cram then called upon W. G. Robbins, Detroit district manager of the Carboloy Co., for his suggestions as to extending the usefulness of tungsten-carbide tools. Mr. Robbins spoke as follows:

Tungsten carbide is in no way similar to steel; it cannot be cast, forged, rolled or turned. It is made of tungsten, cobalt and carbon by molding and heating twice in an atmosphere of hydrogen. After the first heating, it can be cut and formed. After the second heating, it is harder than the sapphire or any other known substance, except the diamond, and virtually the only way to change its form is by grinding.

The material is uniform throughout; it will always give the same life per

grind. As to its strength, it is stronger in compression than any other known material and about one-third as strong as high-speed steel in tension, and it has absolutely no modulus of bending. When loaded sufficiently as a beam, it will break without deflection. Its density is about twice that of steel, and its coefficient of expansion is only about one-fifth that of Invar steel or 1/20 that of ordinary steel. Its brittleness depends upon its support and how it is struck. It cannot be broken like glass if it is supported properly. A piece of it can be pounded through lead or thrown on an anvil without breaking, but it can be broken like glass if it is placed on an anvil and struck with a hard hammer.

Tungsten carbide cannot be welded to steel, because of the difference in expansion and contraction. Expansion of the steel would cause the Carboloy to break, because of its low tensile strength. Copper brazing allows for the necessary relative movement but can be made to hold the material very solidly to steel. The brazing must be done in an atmosphere of hydrogen, because Carboloy is ruined if it is heated to 1700 deg. fahr. in the open air. The change is not apparent, but the material oxidizes to the depth of about 0.020 in., and its life is destroyed.

Grinding Tungsten-Carbide Tools

When tungsten-carbide tools were introduced, no wheels were available with which to grind them. Now special wheels are available that will sharpen them as easily as Stellite or high-speed steel; the tool can be sharpened just as quickly, although less material is removed. The tool must be passed across the face of the wheel with the lightest possible pressure, otherwise material will be removed from the wheel and not from the tungsten carbide. An outfit suitable for grinding tungsten carbide is inexpensive; the spoiling of a single tool will cost more. Therefore, it is important to learn the correct technique for this material, rather than to try to grind it like high-speed steel or like some other tool material.

Tungsten carbide will cut metal at speeds far beyond those that can be used with other tools, but the feeds must be reduced because of the low strength of the tool. One of the commonest reasons for breakage of tungsten-carbide tools is failure to supply deep enough backing. It is absolutely useless in tool holders that hold ¼-in. or ⅜-in. bits, and bits not smaller than 1 in. are recommended in place of ½-in. bits of other materials. The reason is that the Carboloy cannot deflect without breakage; it must be supported rigidly. The machine-tools also must be very rigid, because constant vibration will chip off minute particles of the tool and make it dull. This dullness causes increased tool pressure and breakage before the tool seems dull enough to grind, according to practice with other materials. The machine-tool needs to be better than the average, all the way down to the lag-screws that hold it to the floor.

Finishing Cast Iron and Steel

Flywheels usually are cast with a considerable amount of surplus stock for finishing, because the castings are subject to chilling, hard spots and scale on the surface. Tungsten-carbide tools can cut through all this, making a large finish-allowance unnecessary. One manufacturer in Detroit is now making in two shifts as many flywheels with tungsten-carbide tools as he formerly made in three shifts. He is now turning the clutch face of the flywheel and securing a better finish than he formerly had by grinding, and 18 grinding machines have been released from this work. By their use, scrap has been reduced from 8 per cent, which was the best previous record, to 0.5 per cent on one large-production job.

Forgings also are usually made with finish allowance sufficient to let the tools cut through the scale, and many forgings must be annealed before machining. With tungsten carbide, neither annealing nor much finish-allowance is needed.

Steel can be finished with tungsten-carbide faster than with any other material, but it is not always a commercial success, because too much material needs to be removed. Much more rigidity, power and chucking ability are required for steel than for cast iron. I know of three really successful production jobs being done with multiple-tool set-ups in this district. They are being done by a manufacturer who had confidence enough in the material to completely redesign the machine-tools that he uses, and now he is reaping a great saving. Not everyone is willing to do that, and successful work on steel may be said in general to be in the future.

The difference between success and failure with tungsten carbide may be made by something very small; for instance, changing the angle at the top of a Carboloy tool ½ deg. on one job made the difference between no production and twice the production that had been secured with the previous tools.

Hard spots and scale offer little resistance to turning, but drilling and sometimes reaming cannot be done under such conditions. Reaming is practicable if sufficient backing can be secured for the tool.

Tungsten carbide is not a cure-all for troubles; rather it is adapted to large-production jobs. One difficulty has been that production men have tried it first on jobs which they are unable to do satisfactorily with other materials. Our advice is to use it first on jobs that are not too difficult, and then to branch out into the harder jobs. Our efforts are being concentrated now on bronze, brass, aluminum, hard rubber, bakelite and cast iron.

In cost, the tungsten-carbide tool is intermediate between the steel tool and the diamond tool, and it has its own place without crowding out any other material. It can replace diamonds for many jobs at a great saving; and for other jobs it can replace high-speed steel, also with a great saving.

Two-Ply Belts Are Advocated

THE COST of a single-ply leather belt 6 in. wide is precisely the same as the cost of a double leather belt 3 in. wide. But the 6 in. single-ply belt will outpull the 3-in. two-ply belt with ease. In other words, single leather belting has higher tractive power per dollar of first cost, because it presents more surface to the pulley. These facts have been used as proof that single-ply leather belting should be used wherever possible.

Nature did not have power transmission belts in mind in her creation of hides; only the duty of a hide to protect the animal inside. She has found that a tensile strength of 2500 lb. per sq. in. is sufficient in the region of the neck. About one foot from there, around the shoulders, the strength is actually twice as great; the maximum of 6000 lb. per sq. in. is reached in the sides.

Is it not obvious that the problems confronting the leather belting manufacturer are not easy if he is to convert what nature has made into leather belts of uniform strength? That it cannot be done perfectly is admitted, but it can be done well.

To overcome the faults of a single-ply belt, the conscientious manufacturer cements it to another belt which is strong where the first belt is weak and weak where the first is strong.

Use double-ply belts wherever practicable, as they are more economical than single-ply belts. — Houghton's *Black and White.*

Transportation Engineering

Urban Traffic-Relief Urgent

Trunk-Line Facilities Needed within Great Cities and in Metropolitan Areas

In considering local versus through traffic on highways and city streets at the 1930 Annual Dinner held in New York City, Jan. 9, Sidney D. Waldon, president of the Detroit Transit Commission, said in part that the definition of local and through traffic varies with the area under consideration. Therefore, for easier understanding, he analyzed the traffic uses of a city street. These fall under two heads: (*a*) local traffic-use calling for access to abutting property whether residential, business or industrial, and requiring a parking or loading and unloading lane, as well as local traffic-lanes; and (*b*) through traffic-use calling for continuous routes free from bottle-necks or other restrictions or interferences, and permitting reasonable speed with safety to the driver, the passenger and the public.

Local traffic may be considered as that which is approaching, entering, leaving or is otherwise essential to a particular block or area. Through traffic is defined as that which is not essential to the block or area that it is passing. But what is local traffic at residence, store, theater or factory becomes through traffic if it has a distant destination. The automobile is essentially a vehicle for fast distance-travel, and has enormously increased the area from which store, theater or factory may draw its customers or workers. It has added hundreds of square miles of formerly inaccessible territory to the residential districts of metropolitan areas. Through traffic is greatest along the most direct routes between business or industrial concentrations on the one hand, and residential areas on the other. The interest of any property, at any moment, in distance travel is also directly related to the number of persons housed, served or employed upon it.

Local and Through-Traffic Differences

The requirements of local and through traffic as here defined are very different. Speed is not the most important consideration of local traffic, while it is the dominating motive of through traffic. When brought together in facilities inadequate to meet their combined needs, there is conflict, and both suffer. Wherever they are to be brought together, wide rights-of-way are essential to provide adequate speed with safety for the through traffic, while still conserving to the adjacent property all its rights to loading and unloading, and local traffic lanes. It certainly is better for any given section of any city to provide one route of adequate capacity for the distance traffic through it than to make such traffic force its way through all of the streets of such a section, with consequent interference with local use as well as danger to life and property. The remaining property in each district would be benefited by the segregation of such through traffic.

If the various sections of a city, metropolitan area, county or State are considered, it will be found that certain routes lend themselves to through-traffic requirements. It will also be seen where such through-traffic facilities are necessary but not provided. Detailed consideration will finally bring together the essential elements of what may be called the *Master Plan* of through-traffic facilities. This may be known as the trunk-line highway-system of the State, or the regional thoroughfare plan of a great city; but, whatever it is called, its principal purpose is to define and ultimately to provide the facilities for through traffic as distinguished from local traffic. The traffic congestion is greatest in the region of great cities because the facilities are less adequate.

U. S. A. Registration-Population Ratios

The United States has one registration to each 4.6 persons. A year ago California had one registration to each 2.87 persons, while five other States had one registration to over 3, but less than 4, persons. It is estimated by students of the subject that the Country as a whole will reach one registration to each 3 persons, and then hold that ratio.

During the 40 years prior to 1920, approximately 55 millions were added to the census figures of the United States. The smallest increase per decade during that period was 11¼ millions, and the largest 16 millions. If we assume that during the next six decades we add 15 millions per decade, then we will have a population of 211 millions 60 years from now. If the ratio of registrations to population holds at one to three, there will be in this Country 71 million motor-vehicles where we have approximately 26 millions today. With an average life of seven years, that would mean an annual replacement-requirement of more than 10 million motor-vehicles per year, giving employment to more than 8 million wage-earners. This fact is worthy of note by the various committees of President Hoover's Conference to maintain a continuing National prosperity.

If this estimated increase in registrations were spread uniformly over the entire Country, it would mean a general increase in traffic of 2.6 times that at present; but, unfortunately, the tendency is unmistakably toward the increase being concentrated in urban centers.

Population Shift Is Rural to Urban

The shift of population from rural to urban has been taking place very uniformly at the rate of somewhat more than 5 per cent per decade. It would only need to continue three more decades before the relationship that existed in 1880, when the rural population was more than 70 per cent, would be reversed and there would be an urban population of 70 per cent. In other words, by 1965 our urban population should have reached 120 millions, with little or no substantial increase in the present rural population.

Do we realize the vital significance of this population shift? It means that the greatest need for increasing traffic-facilities already has shifted from rural to urban areas, with this shift of population, and that increases in population, registrations and traffic, as well as the great bulk of the revenues for increasing the capacity of trunk-line highway and thoroughfare systems, will be found within the urban centers of this Country.

In conclusion, Colonel Waldon remarked that study of the census figures indicates that almost all of the next 55 millions that are added to the population of this Country will be urban. Urban population is growing between eight and 10 times as fast as rural population. Adequate traffic-facilities, plus population, produce motor-vehicle registrations. Traffic and motor-vehicle revenue are directly proportional to registration.

If the public trend toward universal use of the motor-vehicle is a thing to be encouraged as being of benefit to all of the people, he said, this Country must get behind the same sort of broadly designed, cooperative program

for the reconstruction of the trunk-line facilities within great cities and metropolitan areas, as it formerly united behind the program for the creation of our present State and Federal-aid highway systems.

Wise regional planning will reduce cost and increase accomplishment. Through traffic recognizes no municipal, county or State boundaries, and neither should the measures for traffic relief recognize them.

A Message to Fleet Operators

E. C. Wood Believes Personnel Training Essential; Offers Specific Suggestions

ACCORDING to E. C. Wood, superintendent of transportation for the Pacific Gas & Electric Co., San Francisco, one of the most important problems in fleet operation is that of training the personnel in leadership and in executive qualities which enable the members to interpret the policies of the company. "If we do not recognize this fact," he says, "I believe it hampers the smooth functioning of the shop, reduces efficiency, lessens economy and influences the ultimate success or failure of the organization."

An educational program comprising common sense, logical initiative and acceptance of responsibility is all that is required, Mr. Wood remarks. We take loyalty, knowledge of the job and work capacity for granted; without them, men have no business to accept wages or salary from an employer, he continues. "Give me an employe who can accept responsibility and I'll show you a man who gets results," he says.

"What is there about responsibility that makes it so hard to accept?" Mr. Wood asks. One of the great problems of management, he states, is to divide responsibilities and find keen men who can share those responsibilities. The wise superintendent is he who employs automobile mechanics, machinists and clerks, and immediately begins to train them to do what he tells them to do, continuing their training into the post-graduate course of doing things without having been told to do them, thus causing them to assume responsibility. The excuse, "You did not tell me to do that" is altogether too common and it is also somewhat pitiable. Fully 80 per cent of any given personnel can, in Mr. Wood's opinion, be trained to do things on their own initiative if they are schooled into doing so.

Shop Supervision Expensive

Supervision is the most expensive item of shop management, Mr. Wood says. "We spend too little time in making a study of how to get out from under this burden and reduce this cost," he continues. Modern shop-practice demands ability to induce others to do their work properly and efficiently and to persuade subordinate employes to assume responsibility. A shop that is organized into departments that work automatically with minimum supervision and maximum delegated responsibility is bound to operate economically and efficiently. A mechanic in a well-organized shop should be a man who can think and who can work out his own problems, after sufficient time has elapsed for training him. He is an asset and not a liability, and is worth the amount invested in his education. The man who must be forever supervised is not apt to stay very long with an organization, and an organization whose shop force is subject to a high turnover is spending a considerable amount of money.

"So," says Mr. Wood, "let's teach our men the sense of responsibility, give them the opportunity to think, help them to think, encourage initiative, ask them to submit constructive criticism and advise with them regarding their suggestions as to how this and that can be done better, so as to bring about greater economy of operation by holding the personnel to results and not to rules."

In conclusion, Mr. Wood made the following suggestions, which the fleet operator should consider:

Ten Guiding Suggestions Listed

(1) Be fair. Have no favorites and no scapegoats. A superintendent must act as a judge many times a day; therefore, be just.

(2) Make few promises and keep them. A superintendent must be exact in this particular. Sometimes he forgets that his job requires a high standard of truth and honor.

(3) Do not waste anger; use it. Anger is valuable and should be used carefully. Keep your most forceful language for special occasions.

(4) Always hear the other side. Never blame a worker until he has been given a chance to state his point of view.

(5) Do not hold spite; forgive. When you have had to scold a workman, go to him later and tell him his faults in a friendly way.

(6) Never show discouragement. Never let yourself be beaten. A superintendent must have perseverance and possess a never-say-die spirit.

(7) Notice good work as well as bad. Let the worker see that you can appreciate as well as condemn.

(8) Watch for special ability. Take a keen human interest in your workers. Locate each man where he can do his best.

(9) **Take your full share of the blame.**

This is most difficult to fulfill, but the superintendent who can share both the blame and the praise with his workers has discovered the secret of managing men.

(10) Prevent accidents. Educate or eliminate the careless man. The high caliber of his men indicates the good superintendent. He is a safety superintendent.

Speed Is Metropolitan Magnet

Designers of the Silver Bullet Reveal Full Engineering Details and Explain Practical Difficulties at Section Meeting

SOME 300 members and guests were drawn to the meeting of the Metropolitan Section, April 2, to hear Louis Coatalen, managing director of the Sunbeam Motor Car Co., and Frank Martinuzzi, his assistant, tell of the way they attacked the design of a motor-car which was built, from ice tank to tail fins, for the attempt to break the world's straightaway record.

Leaving behind them only unsuccessful attempts at the record, these men came from Florida to keep the engagement they had made for a time when they expected that the trials would be succesfully completed. As a matter of fact, the conditions of beach and wind had been favorable to record attempts only in two days since the team arrived in Florida, and there is only time for two runs in one day on hard sand after the beach has been cleared by the police. Kaye Don, who was scheduled also to participate in the meeting, sent regrets that conditions compelled him to remain in Florida.

The international nature of the meeting was enhanced by the cosmopolitan history of the two speakers. Mr. Coatalen was born and received his education in France, but has been designing motor-cars and airplane engines in England ever since 1902. Mr. Martinuzzi was born in Berlin, studied and became a citizen in Italy, and designed motor-cars and aviation engines in Turin. He has been connected with Sunbeam only since last year. Both Mr. Coatalen and Mr. Martinuzzi are applying for membership in the Society of Automotive Engineers.

A news reel was shown at the beginning of the meeting in which were included pictures of the Silver Bullet being taken from its hangar to the beach, of the tires being changed in preparation for a speed trial, of Kaye Don in the seat and of some test runs along the beach.

Car Designed to Driver's Shadow

Mr. Coatalen began by saying that the difficulties which had been encountered at the beach were due to unforeseen trouble with carburetion. Previous work had been done with the carbureter entirely inside the hood, but the attempt had been made to increase the pressure of the air entering the supercharger by having the carbureter inlet outside the hood and facing forward. As this would disturb the balance of pressures between the carbureter float-chamber and the jets, it was necessary to introduce a balance pipe to equalize the pressure. The balancing had not been effective, neither had larger jets remedied the trouble. Mr. Coatalen said that it would probably be necessary to return to the old system of taking the carbureter air from inside the hood. Later events may be interpreted with this information in view.

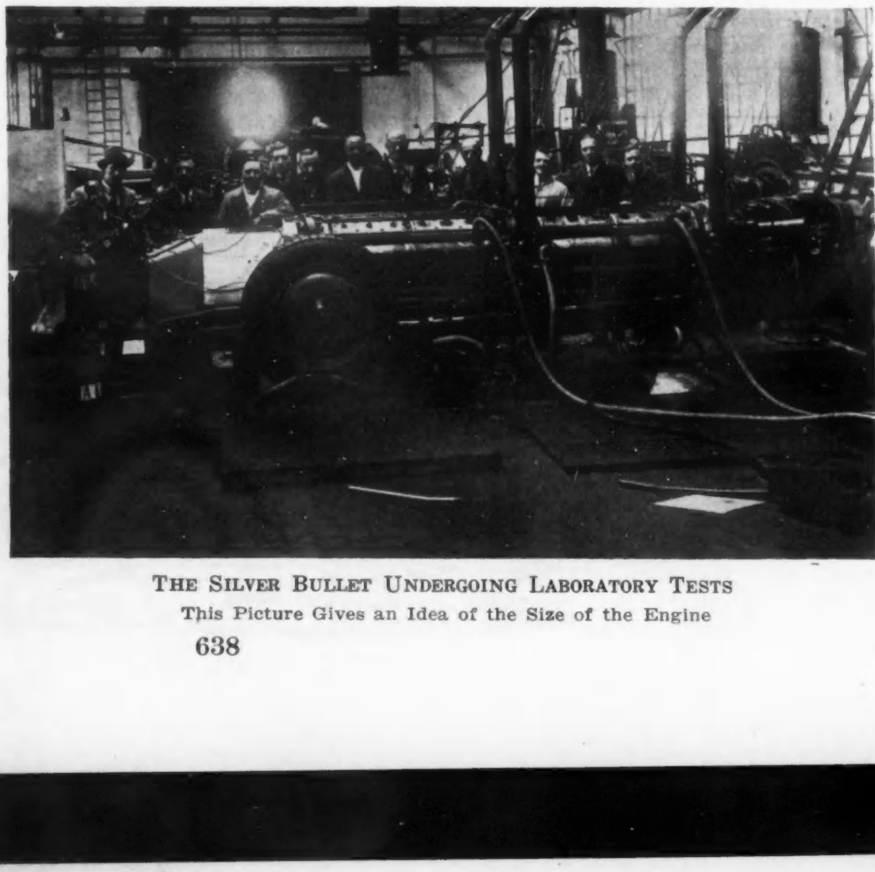
The cars that have made the highest speed records previously have been powered with aeronautic engines. The starting point of this car might be described as building an engine in the shadow of the driver. Every part of the engine that projected beyond the shadow was either lopped off or bent inward. That is the reason why the two rows of cylinders make an angle of 50 deg. with each other, instead of the 60 deg. which is normal for a twelve-cylinder engine. Two engines were required to obtain the power needed, and each is designed for its position in the car. A shaft is provided below the crankshaft of the rear engine to transmit the power from the forward engine, and the accessories are distributed between the two engines to make them work as interdependent units. Many departures were made from normal automobile practice; and these were shown and explained in detail by Mr. Coatalen and Mr. Martinuzzi, with the aid of sectional drawings of all the mechanical parts of the car, photographs and general drawings of which were shown upon the screen. One of the most significant features is the use of split roller-bearings for all of the main and connecting-rod bearings of the crankshaft. This and other mechanical features of the car are covered fully in a description which appears in the Research Department of this issue of the S.A.E. JOURNAL.

Mr. Martinuzzi and Mr. Coatalen also showed photographic views of a number of the aviation engines that have been designed by Mr. Coatalen and built in large numbers at the Sunbeam works for British military service and drawings and charts indicating the construction and performance of an injection system for Diesel engines, also developed by Mr. Coatalen. This is a pressure accumulator or common-rail system, which has been applied to a well-known European engine having injection pumps, making an improvement in speed range and torque characteristics.

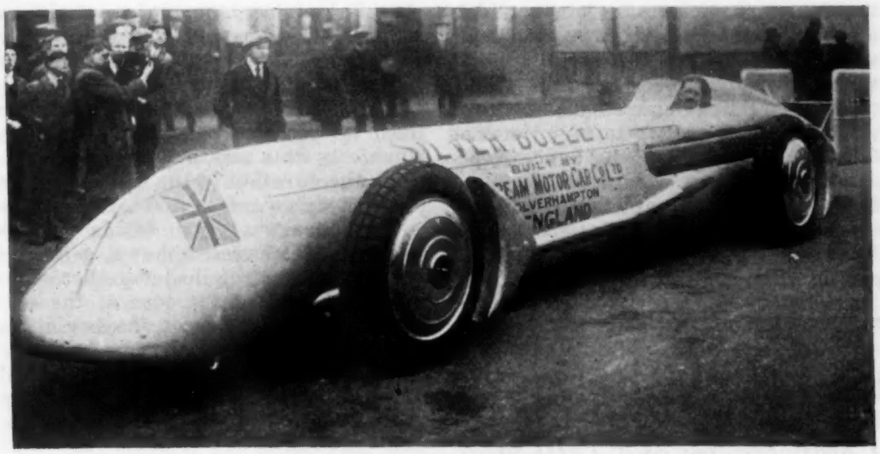
Members Ask for More Details

In spite of the general interest shown in the subject of racing, few prominent racing men were in evidence in the discussion. Edward T. Birdsall, the only man to mention contact with racing, said that his racing experience stopped when Henry Ford left the track. It was once Mr. Birdsall's duty to pay Mr. Ford $100 for each race in which he participated.

Many questions were asked on the engineering and practical details of the



THE SILVER BULLET UNDERGOING LABORATORY TESTS
This Picture Gives an Idea of the Size of the Engine



THE SUNBEAM RACER, KAYE DON AT THE WHEEL

car, and every one was answered fully by Mr. Coatalen or Mr. Martinuzzi. The fuel used was said to be one-half alcohol and one-half benzol plus 3 per cent of ether.

The change from non-skid to smooth-tread tires at the beach provoked a question which was answered by Mr. Coatalen with the explanation that only a very thin coating of rubber can be used on tires travelling at the speeds that are required for record breaking. If the rubber is thick, it will be torn off by centrifugal force. The non-skid tires are simply "slave" tires used in towing the car to the beach.

There was some mention also of the ice-cooling system. Mr. Martinuzzi said that the ice tank holds about 750 lb. of ice, which is sufficient for running the car at full power for five minutes. This is much longer than is required to cover the 8-mile course at an average speed of about 120 m.p.h., as the car is running at full power only about one-half minute of the four minutes consumed. When this information was given, several engineers of the Mack Trucks were seen to be furtively getting out their pencils to compute what the cruising radius of their product will be after they have equipped it with the latest cooling system.

Interest was shown also in the Diesel-engine information given by Mr. Coatalen. Someone propounded the recurring question of how the 0.005-in. holes are drilled in the injection nozzles. Mr. Coatalen replied that that had been a real problem with them until they had located some manufacturers of artificial silk machinery, who produce holes of this order for the dies through which cellulose is extruded. They drill these holes very accurately at a cost of "tuppence" each.

Full-Strength Arc Welds

Milwaukee Section Visits A. O. Smith Plant and Hears Jasper on Electric Welding

ANOTHER illustration of the popularity of plant visits in connection with Section meetings was afforded April 2, when 245 members and friends of the Milwaukee Section responded to the invitation of the A. O. Smith Corp. to make a tour of inspection, which included its famous automatic frame plant. This plant was described in a paper by John P. Kelly in the S.A.E. JOURNAL for May, 1928, p. 565. The inspection trip began at 3 p.m. and was followed by a dinner and meeting at the Milwaukee Athletic Club. Attendance at the dinner was 144, and 24 more appeared before the meeting opened at 8.

T. McLean Jasper, now director of research at the A. O. Smith Corp. and formerly professor at the Universities of Wisconsin and Illinois, was the chief speaker of the evening. He presented a paper on the Electric Welding of Steel, the same that he had presented a few weeks previously before the Western Society of Engineers at Chicago. Arc welding was considered most extensively, but no attempt was made to divulge in detail the welding methods that have been developed at the A. O. Smith plant.

Modern methods of welding are a great improvement over the forge method because they concentrate the heat at the point where it is needed. The problem of welding yields readily to a full understanding of correct temperature control at the welding point. The electric arc has the ability to concentrate and direct large quantities of heat energy, so it is applicable to work that is too thick to be welded easily with torches.

Welds Can Be Stronger than the Plates

Much welding work falls short of its possibilities because many applications of the process violate some of the fundamental laws of physics which are essential to the production of good welding of any kind, according to Mr. Jasper, who said that solid sections 18 in. in diameter have been joined in welds that are stronger than the original steel. Welds of a strength up to 200,000 lb. per sq. in. have been produced, and high characteristics can be obtained in ductility and resistance to fatigue and impact.

Slides shown included one of five test-specimens cut from a weld in a 6-in. plate. Four of these specimens were drilled through the weld with 0.200-in. holes, to the number of 1, 3, 5 and 7 respectively. Every one of the specimens except that with the seven holes broke at some distance from the weld.

Mr. Jasper listed several of the fundamental requirements of good welding and stated that these qualities can be obtained by using the proper welding rod and correct energy balance through the rod, working in a deoxidizing and denitrifying atmosphere, and relieving the welding stresses after the work is completed.

Many imperfections in the welding can be traced to the tediousness of hand welding, and they can be eliminated on important welds by automatic control of the welding arc, which can be made so precise that only slight adjustments are required after the correct combination of rod, voltage and amperage is found.

Tests More Valuable than a Code

A code specifying the exact proceeding of welding is obsolete and fundamentally impossible, Mr. Jasper said, because good welds can be produced in many different ways. The importance of testing welded vessels after completion was emphasized. A part of the weld can be cut out and tested, and the metal can be replaced without difficulty. The regular testing procedure for welded vessels in the A. O. Smith plant includes repeated stresses, a hammer test and stressing the metal to 75 per cent of its yield-point strength. The entire structure must be designed to produce uniform stress conditions under load, if full advantage of welding is to be realized. A considerable saving of material is possible if the joint can be made as strong as the plate itself, in addition to the saving from the elimination of the lap joint and reinforcing strips.

Following the presentation of his paper, Mr. Jasper showed pictures from the A. O. Smith plant, including arc welding in progress and other pictures

bearing upon the production and testing of welded containers.

Welding was brought more specifically into the realm of automobile manufacture by William C. Brady, a Chicago welding specialist of the General Electric Co., who said that his company has designed and built automatic welding machines that have been applied to the production of rear-axle housings, torque-tubes, propeller-shafts, radius-rods, brake-rods, gear-housings, tire-carriers, universal-joints, shock-absorbers, cross tubes, spring-pad seats and mufflers. Some of these applications involve as many as four simultaneous welding operations, each of which works from two to four times as fast as a man working by hand. Rear-axle housings are welded at a rate of 20 in. per min., complete units being welded in 45 sec. Radius-rods made from 1/8-in. stock are welded at 70 in. per min.

Philadelphia Goes Psychologic

Nathanson Describes Six Basic Competencies and Tells How They Are Measured

ADDRESSING an audience of 53 members and guests of the Pennsylvania Section at the Philadelphia Automobile Dealers Association on April 16, Yale S. Nathanson, of the department of psychology, University of Pennsylvania, discussed the psychological viewpoint of what makes an engineer. His talk covered the methods and equipment used in selecting men for various lines of work and determining the peculiar mental quirks that differentiate individuals. A demonstration of the apparatus used in making psychological tests supplemented his remarks.

The meeting was preceded by a dinner and a short business session at which the Nominating Committee made its report. The names of those who will be candidates for Section offices for the next administrative year are Edmund B. Neil, chairman; W. Laurence LePage, vice-chairman; J. P. Stewart, secretary, and L. E. Leighton, treasurer. At the conclusion of this session, the meeting was turned over to Norman G. Shidle, who introduced the speaker of the evening.

The first part of Mr. Nathanson's remarks described some of the tests that had been made in the past to demonstrate certain phases of psychology and outlined the development of that science. He said that when psychology started out as a formal study, all human ability was divided into approximately 65 groups. As this number was too bulky, efforts were made to reduce it, and a few years ago it was decreased by almost two-thirds. Subsequently, Professor Witmer, head of the department of clinical psychology at the University of Pennsylvania, reduced them to six basic competencies.

All human activities and all the mental display of an individual can be represented by a cube, each side of which symbolizes one of these competencies. These are motivation, control, intelligence, efficiency, intellect and discrimination. The size of this cube is, of course, different for various individuals, and its shape will vary with the balance between these attributes in a person.

Measuring an Individual's Ability

Tests designed to measure the intelligence of an individual and his adaptability for a certain line of work are of two types, mental and performance. In the first group certain series of questions are asked, situations are outlined and the subject is asked to make a decision as to the proper course of action to be followed. The mental tests are graded to indicate the mental age of the subject, and the results obtained, said Mr. Nathanson, are sometimes very unusual. For persons who do not speak English, performance tests, such as giving the subject a set of blocks that are to be fitted together, are tried.

Other tests require the use of instruments. To measure the fatigability of a subject, the ergograph is employed. This is a series of weights that are connected by a pulley arrangement, and by placing a thimble on the middle finger of a subject, he lifts the weights until he becomes too fatigued to continue. In this test a metronome indicates the duration of the test, and a recording stylus traces a record on a revolving drum of the lifting of the weights, which resembles a series of script letter m's joined together. The relative height of the tops of the successive letters indicates the beginning and degree of fatigue.

Reaction time, which is so important in automobile driving and in precision work, is measured by the chronoscope. This consists of two keys, one of which is pressed by the subject as soon as he observes that the person who is giving the test has pressed the other. These keys trace a record of the number of times they are pressed, and this gives a record of the subject's reaction time.

Another instrument demonstrated by Mr. Nathanson was the plethysmograph. This is usually suspended from the ceiling to overcome the possibility of vibration affecting the results, and is designed to record the effect of the emotions on blood pressure and pulse rate. These variations are indicated by the movement of a stylus on a smoked drum. A companion device is the pneumograph, which operates on the same principle and is strapped around the chest of the subject, whose rate and degree of respiration control the movement of a stylus through the actuation of a column of air. Both instruments are used simultaneously, and in employing them the subject is blindfolded and the person giving the test asks him to think of various things.

Sticking the Pin in Opinions

John Warner Tells Canadian Section That Engineers Must Look Beyond Blueprints

IN THE rôle of an iconoclast out to smash some of the idols of the modern market place, namely, automobiles, J. A. C. Warner, of the Studebaker Corp., was the guest speaker at the Canadian Section meeting at the Royal York Hotel, Toronto, on April 16. Some 70 members and friends attended and thoroughly appreciated Mr. Warner's talk entitled, Sticking Pins in Opinions.

Mr. Warner impressed upon his hearers the necessity of being ready to change an opinion so as to keep abreast of the times. An army mule, he said, has no pride of ancestry and no hope of posterity, and the same may be said of the automobile that does not recognize the signs of the times. "We must never be satisfied with our present work," he said. "We must be more or less pessimistic and count our losing tricks, paying more attention to them than to the winning tricks. The man who leans back complacently will be left in the lurch.

"Man buys what woman chooses. We have to recognize that fact,' and the more progressive companies today are utilizing the talent and services of women in the styling of cars. The progressive engineering attitude must involve a sales slant. The engineer who sticks entirely to his slide-rule is more or less passé. He must look beyond blueprints into the pocketbooks of the people who are going to buy automobiles, or he will not build automobiles that the public will buy. The

engineer who does not embrace the opportunity of cooperating with the sales department is extremely short-sighted. And when all is said and done, it is the salesman who pays the engineer's salary."

A number of slides were shown illustrating the primitive forerunners of the automobile, dating back to the 1770's; contraptions which no doubt earned golden opinions at the time but which the pins of progress had punctured as time passed. There was also an illustrated tour through the Studebaker plant.

Mr. Warner interspersed a variety of stories into his address, with the ultimate result that the members did not bring up any more opinions to be punctured, but contented themselves with recalling other jokes, so that the meeting developed into a sort of "That reminds me" club.

The report of the Nominating Committee was read, the members nominated for election at the May meeting being: Chairman, A. S. McArthur, general superintendent, Toronto Transportation Commission; Vice-Chairman, Frank B. Averill, factory manager, Durant Motors of Canada; Treasurer, W. E. Davis, General Motors of Canada; Secretary, Warren Hastings.

In presenting the report, Jack Stewart paid high tribute to the retiring Chairman, R. H. Combs, general manager of the Prest-O-Lite Storage Battery Co., Ltd., and said that the members were unanimous in regretting that, owing to the rules of the Society, he was not eligible for re-election as Chairman.

It was announced that Mr. Baker, of the Willys-Overland Co. of Toledo, Ohio, would be the speaker at the May meeting. C. F.

Lubrication Problems Analyzed

New England Section Given Latest Data on Oils and a Device for Mechanical Testing

TWO PAPERS were presented at the meeting of the New England Section held in the crystal room of the Hotel Kenmore, Boston, April 10. G. A. Round, chairman of the Metropolitan Section and assistant chief of the engineering division of the Vacuum Oil Co., chose as his title, Lubrication. This, he stated, is an extremely controversial subject. The second paper was presented by R. S. Dynes, who described a device by which oils may be tested mechanically. W. M. Clark, superintendent of transportation equipment for the S. S. Pierce Co., Boston, was chairman. More than 150 members and guests attended.

Factors Affecting Lubrication

Mr. Round stated in detail opinions held by authorities on the subject of lubrication with respect to specific gravity tests, color of oils, pour point, flash point, fire point, emulsion and carbon residue tests, and showed lantern-slide views of statistical and other data. "Whenever a high degree of oiliness is attained," he said, "we always get it at the expense of some one of the other characteristic factors." This has been studied by means of the dynamometer, he continued, as regards gumming tendencies; but, no physical specification exists which gives one any clue.

Engine tests were made to determine the tendencies toward rapid oxidization of various oils, Mr. Round said, for 25-hr. periods. Polarized-light tests were made to determine the presence of abrasives in oil. Means of measuring the amount of abrasive contained in oils used in various engines were also described and the character of the abrasives was shown in lantern-slide views.

It was said by Mr. Round that his company is now working on the determination of viscosity at low temperatures, and is making very extensive tests at present with regard to wear. In conclusion, he remarked that the characteristics of oils can be determined only by very practical tests which determine their value.

Oil-Testing Device Described

Five different tests of oils can be made by means of the device described by R. S. Dynes; namely, high tenacity, cold shear test, the point at which fluidity ceases, a bearing test, and a channeling test for transmission greases. The results are plotted in the form of a curve by the device during the test, and the human element is eliminated.

Mr. Dynes gave demonstrations of these various tests and following these answered questions regarding further details concerning them.

Mr. Round stated that the high-tenacity test referred to is a measure of the viscosity of an oil; that is, a stationary and a rotating disc are separated by an oil-film while under pressure. This, however, does not present a means of measuring oiliness, in his opinion. Asked whether he considered iron oxide a sign of metallic wear, he said that it is the result of wear but that it is not known whether this is the fault of the oil or whether it is caused by the silica which enters the oil. He discussed also the relative merits of paraffin-base and naphthalene-base oils.

After answering numerous other questions, Mr. Round said in conclusion that, it is perfectly possible to reclaim oil and make it as good, or even better, than it was originally. In service, an oil becomes contaminated with fuel and water which can be distilled out and it acquires carbonaceous matter and develops acidity which can be treated out; therefore, when reclaimed, it probably is a somewhat better finished oil than it was originally. For practical reasons, reclaiming is not carried to that extent. It does not pay to take the last drop of fuel out of it, and it is not really necessary to bring oil back to its original color to make it a very satisfactory lubricant. If the oil is brought back bright and clear to approximately its original viscosity, the reclamation is satisfactory. Whether or not it pays to reclaim it is purely a matter of economics.

Syracuse Section's First Meeting

Two Hundred Attend Dinner Gathering at Which President Warner Talks on Aviation

THE NEW Syracuse Section of the Society was launched auspiciously on April 17 at the Hotel Syracuse with a dinner attended by 127 members, guests and reporters of the local press, and 200 listened to an address by Edward P. Warner, President of the Society and editor of *Aviation*. Between the dinner and the speeches a demonstration of the new electrical musical instrument, the Theremin, was given by Roger Rawley, accompanied on the piano by Robert Hunter.

Seated at the speakers' table were Mr. Warner, Gordon K. Hood, manager of the Curtiss-Wright Flying Service; Emil Pfleiderer, secretary of the Technology Club, and Chairman E. S. Marks, Secretary L. W. Moulton, Treasurer M. R. Potter, R. B. Beauchamp and Richard Wright, Jr., chairman of the Entertainment Committee, of the Section. Engineer members and other representatives were present in numbers from the H. H. Franklin Mfg. Co., the Brown-Lipe-Chapin Corp., Hubert J. Wright, Inc., the Brockway Motor Corp., the Horstman Oil Co. and the Auto Service Association. Chairman Marks, who presided, introduced the speakers.

The great need of the aviation indus-

try now, according to Mr. Warner, is to have the public as a whole become conscious of the airplane as a vehicle of transportation the quickest and most convenient means of travel. Public confidence and faith in the industry must be reborn, and the commonplaceness of air travel must be impressed upon the public. Aviation is in a process of passing from a "game" to a real business, from being a romantic adventure to an industrial occupation, and from a matter of universal public interest to a public utility.

Mr. Warner said that he recognizes that the cost of operation is one of the obstacles, as is also the difficulty of financing commercial airlines since the Wall Street debacle of last autumn. Nevertheless, he has great faith in the future of the industry. It rests with the engineers now to produce engines capable of driving the planes at higher speeds and to solve the various technical problems of the industry.

Mr. Hood, another guest of the Section, spoke of the progress of Syracuse in the aviation industry, citing facts and figures of the advance made by the city in the last three years. He urged as a civic duty that the citizens support the air mail in particular, using it to its greatest possibilities.

No formal business was conducted at the meeting, which adjourned at the conclusion of the addresses.

East Bay Stages Tractor Meeting

Northern California Section Members Inspect Caterpillar Plant, Hear Papers and See Motion Pictures

THE BROAD range of interest of the members of the Northern California Section was reflected at the March 27 meeting when H. L. Hirschler, Chairman of the Section, mentioned that "we are crawling on the ground tonight and at the Stanford meeting on April 17 we hope to be flying in the air." His reference to crawling was to the tractor meeting, arranged by the East Bay, otherwise the Oakland, division of the Section as the second meeting of the season for which it was responsible.

Approximately one-half of the 150 members present were from the Eastbay division, for which Vice-Chairman Howard Baxter claimed territory extending from Davis, Calif., on the north, where Prof. A. H. Hoffman holds forth, to Sacramento, on the south, where Frank Burnside and R. H. Stalnaker represent the Public Works Department, and from Fresno and Hanford, represented by Mr. Fulprizio and the Nash brothers, to Long Island City to the east, represented by M. R. Clodin.

The meeting started in the afternoon with an inspection trip through the San Leandro plant of the Caterpillar Tractor Co., which was followed by an excellent dinner and a technical session at the plant.

The technical session opened with the election of a Nominating Committee for the election of a slate of Section officers for next season. Those elected to the Committee were: Prof. Lewellyn Boelter, University of California; S. B. Shaw, Pacific Gas & Electric Co.; V. Dennis, Pacific Telephone & Telegraph Co.; Edward Meybem, City of Berkeley, and Milton Fisher, Morris Draying Co.

Upon request by Chairman Hirschler, Prof. A. B. Domonoske, of Stanford University, told the members about plans for the April 17 meeting of the Section, which he said was to be held at the University, where the aeronautic wind-tunnel would be in operation and two papers would be presented.

Vice-Chairman Baxter conducted the rest of the meeting, which was adjourned at 10:35 p.m. without an opportunity having been provided for discussion or the showing of some motion pictures of tractors in snow-removal work. Resolutions were unanimously adopted expressing the appreciation and thanks of the Section to its host, the management of the Caterpillar Tractor Co., for its hospitality and to the speakers of the evening. The speakers were W. H. Radford, general chief engineer of the company, who welcomed his fellow-members of the Section and gave numerous figures of areas and number of employes at the San Leandro and Stockton, Calif.; Peoria, Ill., and Minneapolis works of the company, saying that on their trip through the San Leandro plant the members had seen but one-tenth of the company's works.

Tractor Problems and Diesel Engines

An extensive paper on the Problems Connected with the Design of Track-Type Tractors was presented by H. S. Eberhard, assistant general chief engineer of the San Leandro plant, following which motion pictures were presented showing Caterpillar tractors in logging and various industrial operations.

Under the title, Automotive Diesel Engines, C. G. A. Rosen, the company's engineer in charge of Diesel-engine development, gave a paper the title of which he suggested might imply "a bold suggestion of an established mechanical Elysium, free from travail or grief." But he said that, fortunately for the requirements of material for the paper, such a condition does not exist and he was privileged to devote a little time to discussion of problems of a fundamental character that possibly can be solved adequately only by encroaching on the hinterland of applied science.

Stating almost at the outset that "the present oil engine is not ready to be substituted on a commercial basis for the gasoline engine in the propelling of automobiles, trucks and tractors," Mr. Rosen dealt with the various requirements, the problems involved and the promising attempts made to solve them. In conclusion he stated that "there is opportunity to cull those operating functions which give operating satisfaction and, by persistent research, to so coordinate these factors that a practical solution will be obtained, enhancing the scope and broadening the sales opportunities for the automotive oil-engines."

Spark-Plugs Are St. Louis Subject

THE St. Louis section held a meeting March 18, the report of which was not received in time for publication in the S.A.E. JOURNAL for April. O. C. Rhode, chief engineer of the Champion Spark Plug Co., Toledo, Ohio, was the principal speaker, on the subject which seems most logical for a man in his position.

A nominating committee for Section officers for the ensuing year was elected as follows: George F. Heising, A. O. Payne, George P. Dorris, Mr. Manning and A. J. Mummert; alternates: T. S. Kemble, George C. Stevens, Robert M. Pease, J. C. Cox and William G. Jenkin. A motion picture was presented, showing the manufacture of spark-plugs, beginning with mining the sillimanite in California, and points affecting the performance of spark-plugs.

In Mr. Rhode's talk he emphasized the importance of selecting spark-plugs suited to the engine and the cylinders. Each manufacturer makes plugs of different types, some operating hotter than others under the same engine conditions. A spark-plug should be selected that keeps hot enough to avoid fouling and not so hot as to cause preignition. A range of spark-plugs of different temperature - characteristics were shown, the temperature being controlled largely by the position of the seating of the core. Cores having long surfaces exposed to the hot gases tend to run hotter than those cores having their seats located near to the sparking point.

In practice it is desirable to use "colder" plugs in the Southern States and "hotter" plugs in the Northern States in the same engine. In some cases reported it has proved desirable

for a single fleet operator to use various plugs in different engines of the same type, according to the work they are doing.

Experience has shown that the shape of the electrodes has a marked effect upon starting conditions. Rounded ends were used for both electrodes several years ago, in answer to a demand; but starting troubles caused an investigation which determined the present form of the spark-plugs of one make. The center electrode is milled to a 15-deg. angle, and the other electrode is set as nearly parallel as possible. The points now are set a little closer together than they should be for service; and a saw is passed between them to make the surfaces parallel with sharp edges.

Catalytic metal in the electrodes has been found by Mr. Rhode to correct the tendency for carbon to build up on the electrodes and bridge the gap; but he said that the ideal electrode material still remains to be discovered. Burning of the electrodes is a serious trouble in some communities, particularly in blast-furnace districts where benzol containing considerable sulphur is used.

Mr. Rhode also told of the effect of Ethyl gasoline on spark-plugs. Two classes of Ethyl deposit result: One is a yellow glycerine deposit which gives the appearance of eating into the glaze but actually is harmless and can be removed by chemicals; the other is a yellow-gray fluffy deposit which absorbs carbon readily and indicates that the spark-plug has been running too cold. Substituting a "hotter" type of plug for a plug which accumulates the grayish deposit results in the harmless yellow deposit.

Aviation spark-plugs are designed with safety as the primary consideration. The chief danger to be avoided is breakage that might allow the upper end of the core and the electrode wire to be blown out, leaving an open cylinder. In the aviation spark-plug now produced by Mr. Rhode's company, this mishap is claimed to be made impossible by means of a secondary core or dome of insulating material.

Following Mr. Rhode's talk and some discussion of it, Chairman William L. Dempsey explained the electronic theory with the aid of a lantern-slide, and applied it to the ignition and explosion of the compressed charge in the engine cylinder.

Conflicting Laws Stifle Progress

Pierre Schon Analyzes Legislative Motor-Vehicle Restrictions for Chicago Section

THE effect of legislation on the trend of truck design was the main subject considered at the meeting of the Chicago Section, held at the Sherman Hotel, April 8, the principal speaker being Pierre Schon, sales engineer for the General Motors Truck Co., Pontiac, Mich. The technical session was convened by John O. Eisinger, secretary of the Section, who presided as chairman. About 60 members and guests were in attendance.

At the brief business session held, the members of the Nominating Committee of the Section, F. C. Mock, Harry F. Bryan, J. P. McArdle, J. W. Tierney and John O. Eisinger, presented the following slate for candidates for Section officers for the ensuing year. These are: For Chairman, Elliott W. Stewart, sales manager for the William D. Gibson Co.; for Vice-Chairman, Clarence A. Peirce, vice-president in charge of production and engineering for the Diamond T Motor Car Co.; for Secretary, Otto R. Schoenrock, director of engineering for the Oliver Farm Equipment Co.; and for Treasurer, C. J. Blakeslee, works manager for the Walker Vehicle Co. It was stated that these names would be voted upon by letter ballot. It was thereupon voted to accept the report of the Nominating Committee. Upon the invitation of Secretary Eisinger, the chairmanship was turned over to Clarence A. Peirce, who introduced the speaker.

Legislation as a Motor-Vehicle Problem

"The big idea tonight is transportation," said Mr. Schon, "and the big problem facing the transportation industry today is legislation." Continuing, he said that tremendous changes in motor-vehicles have taken place during the last two years, to such an extent that the improvements made during the last five years are more revolutionary than the combined changes of the preceding 15 years.

Legislation was characterized by the speaker as not having kept step with engineering improvements and, in his opinion, many of our motor-vehicle laws are still in the dirt-road or the gravel-road stage and were formulated to control motor-vehicles that were equipped with solid tires. One State allows only a gross load of 16,000 lb. regardless of the number of wheels or axles, he said, and no vehicle having a greater weight can operate in that State.

In line with the advice given by a prominent Federal committee, which, as quoted by Mr. Schon, crystallized into the few words: "To revive business conditions in this Country cultivate dormant markets," the speaker stated that more than half of the States in the Union are dormant markets for heavy-duty motor-trucks on account of the restrictions on motor-vehicles existent in the laws of these States. He then enumerated the changes and improvements that have been accomplished in the design of motor-trucks in the last few years.

The reasons for both changes in design and changes in operating methods for motor-vehicles are good roads, faster vehicles that are capable of traveling at still higher speeds, pneumatic and balloon tires as compared with solid tires and the fact that we now possess long-distance transportation, as stated by Mr. Schon. Following a survey he made recently for one of the large railroad companies in this Country, he compiled a report covering the possible operation of motor-trucks in 14 States. In the first paragraph of the report he stated that standardized design of vehicles was impossible because there were 14 different types of regulations in those 14 States. In other words, conflicting laws were interfering with putting that particular project through. He stated also that the railroad companies are operating at present more than 10,000 motorcoaches and motor-trucks and, in his opinion, the railroad companies will become the largest users of motor-trucks. He based this opinion partly on his own experience and partly on an article recording an interview given by President Atterbury, of the Pennsylvania Railroad, and published in the *American Magazine* for April, 1930, on p. 16. In the speaker's opinion, this article presents the picture of transportation in its broadest scope. He then cited numerous bills unfavorable to motor-vehicle transportation that have been presented to the legislatures of Michigan and other States. Only through strong State organizations of sufficient membership and sufficient power can such legislation be eliminated or offset, he said.

Maximum Dimensions and Weights

Mr. Schon stated that his organization has formulated a tentative set-up on maximum dimensions and weights of motor-vehicles, and showed numerous lantern-slide views, illustrating this scheme, while making comments regarding the most important features. Included also were views of typical vehicles, inclusive also of tractor and trailer operations.

The discussion consisted of comments and queries on various points brought out by the statistical and other data. These related to maximum height, length, width and weight of vehicles; classification of highways; carrying capacity of tires; taxation and kindred subjects.

Beauty in Utility Design

Architect Tells Detroit Section Cars Will Be Put in Museums —Body Details Criticized

BODY designers and engineers first squirmed in their seats and later grinned complacently at the March 24 Body Division meeting of the Detroit Section at the Book-Cadillac. At the 5 o'clock technical session Ralph E. Bills, president of the Ralph E. Bills Body Co., of whom Chairman H. R. Crecelius said that his training goes away back to carriage days and that he has had to correct some of the evils of body design and construction in service work, dissected present automobile bodies verbally and told his hearers wherein they fall short of producing bodies that are perfect as regards quietness, durability, good appearance, tightness against rain and wind, lightness, hardware, safety and so forth.

Mr. Bills's criticisms were more constructive than destructive and contained many suggestions that, if taken to heart and acted upon, should result in much improvement in bodies of the near future. That he touched numerous tender spots in the minds of his audience was indicated by the large number of questions asked at the conclusion of his talk, which brought out much more good information and advice in Mr. Bills's answers.

Drooping Spirits Revived

Whatever disheartenment, if any, was caused by the pointing out of body defects in the technical session was dispelled by the dinner and the entertainment provided by a double quartet of young colored boys, and was turned into joy and hilarity in the after-dinner jovial discourse on body beauty as seen by an architect. The speaker who honored the Section in this way was Raymond M. Hood, eminent as an artist, architect and engineer and as president of the Architectural League of New York, trustee of the Beaux Arts Institute of Design, and member of the Architectural Commission for the Chicago World's Fair which is to be held in 1933.

What body designer or engineer is so immune to praise that he would not be gratified to be told, as the Detroit Section members were told by Mr. Hood, that

"Your cars are marvelous looking machines that 50 years from now you will find in the museums exactly as you find armor, rugs, furniture and everything else; they are real works of art, and it is because of sincerity of attack that you have arrived with such a result, because you have gone consciously at the building of a fine autobile, and unconsciously this spirit of beauty has arrived in them"?

No little courage was displayed by Mr. Hood in accepting the invitation to appear before the Section and make the kind of talk he gave, not that he cared what the automotive men would say, but because he drew some invidious comparisons between art in the automobile field and art in architecture, furniture and interior decorating; and several critical architects were seated in the audience. His theme throughout was that real beauty comes through the qualities of practicability, serviceability and utility. "Wherever any claims at all can be laid to beauty," he said, "that one common factor is always this factor of practicability and utility. From an architect's point of view, I say stick to designing the car solely and purely from the point of utility, studying the shape that absolutely serves the purpose best; choose every material in the same way regardless of whether it satisfies some old formula of beauty. Beauty is a sort of elusive thing; it doesn't come when you chase it. Simply settle down and do your business of making an automobile, and the beauty will come of itself."

Mr. Hood remarked that he did not mean that one should not study and search for beauty. The designer or body engineer will inevitably be confronted many times with the necessity of exercising all the discrimination of the artist in choosing among several materials that will serve equally well, in arranging a door or the fenders and so on. At such time he will need all the good taste and artistic ability he can command.

Valve-Action Study Demonstrated

Jehle Modifies Laboratory Apparatus to Project Results Directly onto a Large Screen

PERHAPS the clearest idea we can give of the meeting of the Cleveland Section, held April 14, is by comparing it to a flea circus, in which the fleas are made to look like alligators as they ride their bicycles across a screen. The meeting was held in the Ball Room of the Hotel Cleveland, and followed a dinner and entertainment.

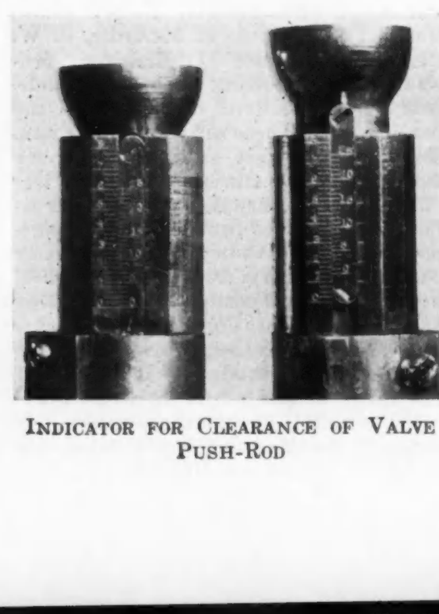
Ferdinand Jehle and E. J. Spiller gave a paper at the 1929 Annual Meeting in which they described a mechanism for indicating valve lift and valve-spring surge, together with a number of photographic diagram records made with this indicator. This paper and its discussion appeared in the S.A.E. JOURNAL for February, 1929, p. 133, and March, 1929, p. 327. The apparatus as described at that time had one serious defect, from the point of view of a showman; it was like the flea circus in that the performance could be seen by only a few at a time, although a photographic record could be made from it. Evidently Mr. Jehle has been studying this question with his many theatrical friends; at least, he has found a way to remedy the defect for the purpose of this meeting.

As used in the laboratory, the valve-lift indicator makes a record only 2 or 3 in. high, but Mr. Jehle has modified it so that the indicating beam can be projected directly onto a motion-picture screen. In this way he was able to transform what had been only as large as a flea circus into a demonstration that could readily be seen by the 175 people who attended this meeting.

The mechanism in question includes a replica of an engine valve and its operating mechanism, to which is attached apparatus for projecting beams of light to indicate the valve lift and the motion of the valve spring. For laboratory work, this beam is projected onto a small screen where it can be studied visually or recorded on a photographic film. For the purpose of this meeting, the machine was modified to throw its beams to a motion-picture screen.

Tracing a Room-Size Diagram

Before showing the machine in actual operation, Mr. Jehle showed how vertical motion of the valve gave vertical motion to a spot of light on the screen and how rotation of the mechanism



INDICATOR FOR CLEARANCE OF VALVE PUSH-ROD

gave horizontal moton to the same spot of light. Turning the valve mechanism by hand caused the spot to trace a path on the screen that represents a valve-lift diagram. When the mechanism is running at speed, persistance of vision makes the path of the light spot appear as a diagram on the screen. After demonstrating this, several double diagrams were shown in which the difference between the motion of a valve on a certain cam at low speed and at high speed appears, thus demonstrating imperfection in the valve mechanism.

He then showed a series of harmonics of a valve-lift curve, determined by computation, and a diagrammatic drawing of the mechanism by which vibration of the valve-spring produces a wavy shadow across the same negative which records the valve-lift curve. In the machine as modified for this meeting, this shadow also was thrown on the motion-picture screen.

Projecting again from the machine itself, Mr. Jehle demonstrated the light thrown from the slot under different conditions of manipulation and then ran the machine so as to show how the diagrams were produced. After this, the machine was operated at various speeds from 573 to 1050 r.p.m. noting spring vibration that occurred at various harmonics from the twentieth to the eleventh—including the twenty-fifth, which occurs between the thirteenth and twelfth—and the absence of harmonic vibration between these periods. The machine was then allowed to coast to rest from high speed, with the various vibration periods of the spring appearing on the screen.

The valve-spring used in this demonstration was selected to show vibrations rather than as a demonstration of a good mechanism. Because of the time that would have been required for changing to a spring that would demonstrate better action, laboratory records from good springs were shown by means of slides.

Valve-Clearance Indicator Demonstrated

An indicator for valve clearance, which was not described in the paper to which reference has been made, also was demonstrated by Mr. Jehle. This consists of a polished Vernier gage that can be inserted in the valve push-rod to indicate the clearance. The light from an electric lamp is concentrated on this scale by a lens, and an enlarged image of the scale is projected through a telescope to a screen. The scale can easily be read on the screen while the engine is in motion, because the valve is on its seat during so large a proportion of the time that the image seems to remain at rest when the engine speed is more than 200 or 300 r.p.m. In this way, the effect of load, temperature and other operating conditions on valve-push-rod clearance can be studied while the engine is in operation.

The operation of this indicator also was demonstrated on the screen. Changes in clearance, such as would be caused by temperature differences, were made by introducing feelers in the mechanism. Mr. Jehle's paper closed with slides showing diagrams of clearances for both inlet and exhaust valves under different conditions of speed and load, as plotted from laboratory work with the indicator he demonstrated.

A lively discussion of the paper ensued, among those who participated being B. H. Blair, of the Eaton Axle and Spring Co.; A. T. Colwell, of Thompson Products, Inc.; H. Hoy Clark, of the Cleveland Wire Spring Co.; Chairman W. E. England and Lyle K. Snell, of the Eaton Axle & Spring Co. Mr. Snell introduced the question of temperature and the durability of valve-springs. Tests that he has made on the endurance of car springs seem to show that they will stand many more flexures if the temperature is kept down to 60 deg. fahr. than they will if the temperature is allowed to rise to 165 deg. fahr.

Variety at Northwest Meeting

Addresses on Locking Differential, Liquid Oxygen, Bearing Metals and Lubrication Given at Seattle

VARIETY being the spice of life, the April 4 meeting of the Northwest Section in Seattle, Wash., was anything but monotonous. The meeting opened with the introduction by Chairman Robert S. Taylor of those in attendance, who rose as their names were read from the registration cards and announced their company connections. Sherman W. Bushnell, Chairman of the Section Nominating Committee, then reported the nominations for Section officers for next year as follows:

Chairman—Donald F. Gilmore, manager maintenance department, Sands Motor Co., Seattle

Vice-Chairman—Walter R. Jones, president, Willis-Jones Machinery Co., Inc., Seattle

Secretary—C. H. Bolin, general motor-vehicle supervisor, Pacific Telephone & Telegraph Co., Seattle

Treasurer—C. C. Finn, Pacific Northwest manager, John Finn Metal Works, Seattle

The next piece of business was consideration of a proposal for a week-end summer meeting of the Section to be held in May or June. Mr. Keymore, of the Seattle City Light Department, outlined a schedule and gave detailed information regarding a trip to the 1,000,000-h.p. hydroelectric power development at Skagit, 170 miles from Seattle, which he said is "one of the most wonderful trips in the world." The program, as outlined, would include a 110-mile ride to Rockport, a 60-mile ride on the City Railroad, a hike across the suspension bridge at Newhalem to the small powerhouse under construction, supper at Newhalem, inspection of the 75,000-hp. gorge powerhouse, a visit to the illuminated waterfalls, a night on cots in the buildings at Newhalem, breakfast early Sunday morning, followed by rides on the railroad 7 miles to the Diable tunnel, now under construction, with an ascent of the 68-per cent 558-ft. inclined railroad, inspection of the work in process on the dam, return for luncheon at Newhalem, and the return trip to Seattle.

After Mr. Keymore's talk and his assertion that 150 men and women could be accommodated, at a cost of $2 for the three meals, 60-mile ride on the City Railroad and use of a cot, all those present at the meeting were unanimously in favor of going.

Differential for Six-Wheel Vehicles

First on the technical program was a paper by Harry M. Patch, research and development engineer, illustrating and describing a locking differential for application to four-wheel-drive six-wheel vehicles. In the absence of the author, the paper was read by Mr. Bushnell. The purpose of this development is to compensate for the different wheel or axle speeds and at the same time prevent the slipping of a wheel that loses traction and thereby apply the power to the wheel that retains traction.

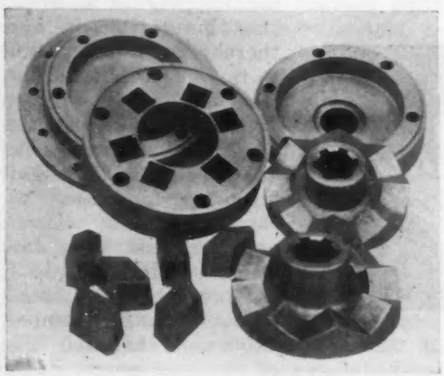
Briefly, the differential consists of a pair of axle gears each having eight large flat-face teeth as shown in the accompanying illustration and which are driven by half a dozen specially formed blocks that are mounted on a carrier interposed between the toothed faces of the axle gears. The blocks work in diametrically opposite pairs and make sliding surface contact with the gear teeth. In action, if one

axle gear advances in speed over that of the differential housing, the other gear will be retarded, as with the conventional differential, the blocks, which are free to move axially in their carrier, moving in and out of the teeth of the axle gears. When one driving wheel loses traction, "the blocks are forced to attempt to impart their movement to the opposite axle gear, which generates so much friction on the faces of the teeth that the gears are forced to travel in unison, allowing practically all of the power to drive the wheel retaining traction." Even though three wheels lose traction, one wheel retaining traction will propel the vehicle, according to Mr. Patch, and operation for a period of months and covering several thousand miles has proved that the differential will do what is claimed for it.

Liquid Oxygen Demonstration

An interesting demonstration of liquid oxygen was next given by Mr. Jones, of the Air Reduction Sales Co., who mentioned as an advantage of chilling bushings with the product that a smaller clearance can be obtained with a chilled bushing than with a driven bushing and no tool marks are left on it. In answer to questions, he stated that the rate of evaporation of the liquid oxygen is about 20 per cent in 24 hr., that the expansion is so great that it cannot be kept "corked" in the "glorified thermos bottle," that it is used extensively in strip coal mines in the South for loosening and breaking up the coal, and that chilling hardened metal with it has no permanent effect.

A talk on bearing alloys was given by C. C. Finn, who has spent all his life in the metal business in San Francisco and the Northwest. He said that the only metals of which he knows that are used with success as alloys for babbitting in automobiles are copper, tin and antimony. They alloy perfectly in all proportions and the tin is extraordinarily tough and can be reduced to translucent thinness. If lead is added, it reduces the coefficient of friction, resulting in a polished surface and also destroys the ability of the tin or antimony to retain the copper, producing a sluggish alloy that becomes brittle. The brief discourse was illustrated with drawings on the blackboard and the speaker showed samples of bearing castings.



PATCH LOCKING DIFFERENTIAL, EXPLODED, SHOWING GEARS, CARRIER AND BLOCKS

Cleanliness Saves Oil Cost

"If one keeps the lubricating oil clean, it is possible to save the entire cost of the oil through the decrease in engine maintenance," asserted the next speaker, Mr. Brace, of the National Refining Co. He talked about dilution and contamination, and their effects on the wear of the engine; refining processes; difference in size of molecules of the various constituents of crude petroleum; and the effect of engine heat on the molecules. The business of his company is the re-refining of used crankcase oil. After treating it to remove the foreign matter, the oil is distilled by steam vacuum to remove unburned gasoline and broken-down oil molecules. In practice, his company finds, he said, that the re-refined oil does not dilute as much as new oil. How many times crankcase oil can be re-refined and reused, Mr. Brace said he does not know, but the General Electric Co. in some experimental work done in 1925, 1926 and 1927 repeated the process 80 times "and got tired and quit." The speaker also discussed briefly the various oil tests such as flash, fire, carbon residue and viscosity.

What time remained of the evening was spent by the members in asking Mr. Brace questions on the subject of lubrication and re-refined oil and his further explanation.

Round Engines Are Compact

Indiana Section Shows Interest in Unconventional Engine of Australian Origin

ENGINES having cylinders parallel to and equidistant from the main shaft sometimes have been called barrel engines. E. S. Hall, who gave a paper on such engines for the Indiana Section at its meeting on April 10, says that some of them bear little resemblance to a barrel, and it is more correct to designate the class broadly as "round" engines. More than 100 members and guests attended this meeting, which followed a dinner in the Chateau Room of the Claypool Hotel at Indianapolis.

Four types of round engine were described by Mr. Hall, who is chief engineer of the Michell-Crankless Engines Corp., New York City, and illustrated by numerous patent drawings and other illustrations. The type classifications are: (*a*) the cylindrical cam, driven by roller followers; (*b*) the conic crank; (*c*) the wabble plate and (*d*) the swash plate. The cylindrical-cam design is said to have possibilities for scavenging by designing the cam to give four strokes per revolution, with a long exhaust stroke. One design shown required three revolutions for one stroke. The engine described in the paper by H. W. Earl in the S.A.E. JOURNAL for March, p. 341, evidently belongs in this classification.

The wabble-plate design involves an angular crankpin on which a plate wabbles without turning, the conic-crank type differs in having the angular crankpin extending to one side only of the main shaft, and it makes provision for carrying the axial thrust on the engine frame. The swash plate differs from the wabble plate in that it is part of the main shaft or attached solidly to it and rotates with it.

Mechanisms of these various classes have been applied in the past to steam engines and pumps of various sorts, as well as to internal-combustion engines.

Slipper Bearing Is Essential Feature

Australia was the birthplace of the Michell Crankless Engine, which is of the swash-plate type. Its most distinct characteristic is the self-adjusting slippers which ride on the "slant," as the swash plate is called. These slippers are based on the same principles as are used in the pivoted-segment thrust bearings, which were invented contemporaneously by A. G. M. Michell, of Melbourne, Australia, and Albert Kingsbury. These bearings have been widely used for turbine and marine-propeller thrusts and are recognized for their ability to carry intense loads with very little friction, because of the wedge-shaped film of oil which the slipper induces.

The "slope" of the Michell engine is made thick, so that it acts as an engine flywheel. Parallel cylinders may be equally spaced around the engine shaft, either on one side or on both sides of the "slope." Mr. Hall stated that engines of this type can be designed with perfect balance, instead of the approximate balance attained in the ordinary multi-cylinder engines. Four-cycle engines can have equally spaced explosions with an odd number of cylinders in a single ring or with either an odd or an even number of cylinders in each of two rings.

Engines, pumps and blowers of this

design are said to have been in successful operation for some time, and to operate with a mechanical efficiency that compares favorably with that of conventional engines. Among the units shown by means of the slides were a small crankless water-pump, driven by a 3-hp. electric motor, and a 300-hp. gas engine driving a gas pressure-booster of large capacity and equipped with an auxiliary starting engine. All three of these units are of the Michell Crankless design.

Lubrication Excites Interest

Discussion of the distinctive features of the Michell engine was participated in by W. Guy Wall, Harry M. Bramberry, Louis Schwitzer, Charles A. Trask, Prof. H. M. Jacklin and Chairman Bert Dingley. The optimum angle of the "slope" has not been definitely determined, according to Mr. Hall. Most of the units so far made have used an angle 22½ deg., but he believes that a smaller angle will be slightly more efficient. Mr. Wall asked in regard to the application of slipper bearings to the crankshafts of small engines; and Mr. Hall replied that Mr. Michell, who is a recognized lubrication expert, sees a chance for a slipper bearing everywhere, but the complication is considerable for the space available in a small engine of the conventional vertical or V type.

Lubrication was discussed also as to the thickness of the oil film and the effect of centrifugal force. Mr. Hall reported that the oil film is about 0.002 in. at the entering edge and 0.00075 in. at the trailing edge of the slipper, varying according to the viscosity, temperature and other conditions. The slippers are said to show no wear so long as the oil is kept reasonably clean.

The compactness of the engine is such that the cubical contents of the smallest rectangular box that will contain it is about one-half that of a corresponding box for a conventional engine of the same displacement. An airplane engine has been built that weighs 1½ lb. per hp. An automobile engine is being built with a displacement of 359 cu. in., to develop about 120 hp. It is expected to weigh about 650 lb. The engine is 35 in. long, not including the projecting shaft, and approximately 22 in. wide and 22 in. high. Mr. Hall believes that a design of rotary valve has been found that will operate to advantage in the crankless engine, making it simple and capable of exceptionally high speeds. An engine embodying this valve has been operating for over two years.

Californians Inspect Wind-Tunnel

San Franciscans and Oaklanders Turn Out in Strength at Stanford University Meeting

DRAWING cards at the April 17 meeting of the Northern California Section, which was held at Stanford University, at Palo Alto, by arrangements made by Prof. A. B. Domonoske, executive head of the mechanical engineering department, were a dinner at the Stanford Union; an inspection of the university wind-tunnel and aerodynamic laboratory; the showing of air-flow by means of ultra-rapid motion-pictures made at the Imperial University in Tokyo, Japan; and an address by Prof. Alfred S. Niles, professor of aeronautic engineering at the university. Nearly 100 members attended the dinner, and 25 students joined them at the technical session and inspection trip through the tunnel and laboratory following the dinner.

With Professor Domonoske leading the way, the attendants passed quickly through the pressure or balance chamber of the tunnel, which the "bell wether" reassured them in advance would not be in operation while they were going through and observing the apparatus. Then they observed the tunnel from the outside, noting the wind velocities and the measuring devices when the fan was up to high speed. They also inspected the water channel, which is a small stream that is sprinkled with floating dust and circulated by suction to show how eddies form about an air foil. The effects, said the speaker, are qualitative, not quantitative.

"Business" Precedes Pleasure

Chairman H. L. Hirschler reconvened the meeting for a business and technical session in the engineering building after the inspection and Howard Baxter, Vice-Chairman representing the East Bay division of the Section, called upon the members from that division to show their strength—in number—by standing, whereupon about one-third of those present arose. He then expressed the appreciation of the East Bay members for the opportunity of "sitting in here tonight at this seat of learning" and, as a token of "genuine friendship and appreciation of this hospitality," presented to Professor Domonoske "the genuine Stanford ax that we captured about 31 years ago." When displayed, the ax proved to be made of paper, and Chairman Hirschler explained that Mr. Baxter was a member of the class that captured the original ax, the whereabouts of which doubtless still remains a closely guarded secret.

In the unaccountable absence of Prof. Llewellyn Boelter, Chairman of the Nominating Committee, who may have got shut in the wind-tunnel, S. B. Shaw gave the report of nominations for the next year's Section officers as follows:

Chairman—Dr. Edward Zeitfuchs, research engineer, Standard Oil Co. of California, San Francisco.

Vice-Chairman — Howard Baxter, president, Howard Baxter Automotive Service, Oakland, Calif.

Vice-Chairman, representing East Bay—Carl Abell, sales engineer, Hall-Scott Car Co., Berkeley, Calif.

Treasurer—C. J. Vogt, instructor in mechanical engineering, University of California, Berkeley.

Secretary—W. S. Crowell, claims adjuster, Home Accident Insurance Co., San Francisco.

Rapid Motion Pictures Explained

Preceding the showing of the Tokyo rapid motion pictures, Prof. Elliott G. Reid stated that the first copies in this Country were made through the courtesy of the Society of Mechanical Engineers and that Stanford University was fortunate enough to obtain a copy last year. He then explained the apparatus with which the pictures were made and stated that the last section of the film was made with exposures at the almost unbelievable rates of 10,000, 20,000 and 30,000 exposures per second. The film shown was taken primarily to show the air-flow around airplane wings, cylinders and a model of an autogiro. The variations in air density caused by the waves was shown by a novel method, developed by the Japanese, which depends upon the refraction of light with variations of air temperature. Upstream of the object to be photographed, Professor Reid explained, a series of parallel wires, heated by an electric current, heat the air in strata, causing bands of lighter and darker values on the film when the objects and the surrounding airstream are suitably illuminated.

Government Airplane-Design Regulation

Department of Commerce requirements for airplane safety and the procedure followed in licensing a new design were discussed by Prof. Alfred S. Niles. Tests that propellers are required to pass were dealt with first, reference being made to the $300,000 test equipment at Wright Field. The speaker next told of the three tests that engines must pass and said that this work is turned over to the Bureau of Standards, which has excellent facilities for it.

Although the airplane manufacturer does not have to worry much about the engine and propeller when he desires an approved-type certificate, he has plenty of trouble, according to Professor Niles, as he must send a complete set of duplicate detail drawings, usually numbering not less than 40 or 50, and a stress analysis to the Department of Commerce with his application. The drawings are carefully examined by the Department engineers to see that the designs do not include any bad practice, and the stress analysis are checked completely, even to verifying all the mathematical calculations. If the drawings and analysis are found to be all right, the drawings are stamped with the seal of the Department and returned to the manufacturer and are his authority to use the dimensions in his airplanes.

When the stress analysis has been approved, the Department is willing to grant an approved-type certificate, as far as that plane is concerned. However, an inspector goes to the plant and checks up to see that the plane is in conformity with the drawings and on the quality of the material and workmanship. Then he takes the airplane and gives it a flight test. It must meet certain requirements such as a landing speed of not more than 60 or 65 m.p.h. according to the type, take-off within 1000 ft., climb at a rate of 400 ft. in the first minute, ability to make five figure 8's without excessive loss of altitude, and, if it is a multi-engine plane, it must be able to fly with one engine dead. Small planes of less than 4500-lb. weight must come out of a spin, after making six turns, in less than 1½ additional spins with power off and controls in neutral. If a plane meets all the requirements, the builder gets a final approved-type certificate and a license for the particular airplane. Duplicate planes may then be built and will be licensed more or less automatically, although each must be checked for location of center of gravity, weight and to see that it is essentially like the first one.

Professor Niles gave various other details of ways in which the Department operates to assure safety in the air.

Just before the meeting adjourned Dr. Zeitfuchs announced that at the May meeting of the Section Howard A. Reinhart, sales engineer of the Ethyl Gasoline Corp., is to talk about work that Earl Bartholomew, director of the corporation's engineering laboratory in Detroit, has been doing on engine diagrams and of the economy that is obtained by using ethyl gasoline.

Aeronautic Addresses Given at Wichita Meeting

NARRATION by A. W. Mooney of his making of an unofficial record for duration and distance for airplanes of less than 100-hp. was the leading feature of the April 16 meeting of the Wichita Section, which was held in the Lassen Hotel and attended by 50 members. On the recent flight, the speaker flew a Mooney low-wing monoplane powered with a Kinner 90-hp. engine. He took off from Los Angeles and landed near Fort Wayne, Ind., having made a non-stop flight of 1980 miles in 22 hr. 27 min.

Following the address, the technical features of the airplane and the flight were discussed by the members.

A second address was made by Mr. McCutcheon, of the Stearman Aircraft Co., also of Wichita, who discussed airplane dopes and lacquers, giving an engineering outline of the materials used for fabric finishes, supplemented with facts about their chemistry, methods of manufacture, the causes of failure and means of prevention.

Discussion of the subject indicated that adequate control of temperature and humidity and a correction of methods used in application are essential to obtain satisfactory finish.

Vane Pump Adapted to Fuel Feed

THE Buffalo Section meeting at Hotel Statler, April 1, drew an attendance of 100, to hear E. W. Dilg, of the Evans Appliance Co., of Detroit, describe a new gasoline pump of the rotary type, having sliding vanes pressed against the cast-iron housing by springs.

Vapor lock is said to be eliminated by this pump, because of its capacity and the sealing effect of a patented method of feeding oil to the vanes under pressure. Nitralloy is used as the material for all the moving parts, and the pump is provided with an adjustable bypass valve to regulate the gasoline pressure. Charts were presented to show the priming ability and delivery capacity of the pump and the pressure delivered at various speeds, and sections were shown of the fuel pump, the bypass valve, and a combination pump for lubricating-oil and fuel. This combination is made with a single shaft and both pump elements of the same type.

A wear test of 900 hr. continuous running at 1800 r.p.m. is said to have shown not over 0.0002 in. wear at any point excepting at the outer edge of the vanes. The wear of 0.002 in. at this point is taken up by the spring pressure. The oil consumption is given as 1 qt. for 5000 miles.

Discussion following the presentation of Mr. Dilg's paper elicited the information that the cost of a pump of this sort is materially less than that of a vacuum tank and the opinion that it will be much more reliable because of its simplicity.

Noise from this pump is confined to that caused by the ball check-valve, which vibrates on its seat when the gasoline used by the carbureter is nearly as much as the capacity of the pump. At a speed of 200 r.p.m., the gasoline passing the valve keeps it off the seat. The pump is said to prime itself from a 40-in. suction head within 25 sec. at 25 r.p.m.

The meeting closed with an interesting description by Edward Evans of a trip around the world which he had made recently.

Rolling-Mill Visit

THE Dayton Section turned out 100 strong for the inspection trip through the American Rolling Mills at Middletown, Ohio, which constituted the chief feature of the April 21 meeting. Eighty persons attended the dinner at the Manchester Hotel in Middletown, where Vice-President Chapple, in charge of advertising for the Armco Co., gave a preliminary talk. Afterward they were joined by 20 more and made an interesting and colorful trip through the mills, seeing the latest developments in the equipment and processes.

Detroit Aeronautic Meeting

(*Continued from p.* 541)

launched gliders were flown by representatives of various Glider Clubs, and exhibitions of glider launching by means of automobile towing were given.

The spacious airport was alive with action and the throngs of visitors were kept busy watching the flights. Many airplanes of numerous types were on the field and these were also a source of interest in that they were continually either taking off, flying over the airport or landing.

The scene of the glider demonstrations was adjacent to the Aircraft Show exhibition buildings. Hundreds of automobiles were parked outside the field and the occasion was also an unique demonstration of aeronautic activity not only by professionals but by amateurs. Among the glider clubs represented were those of the University of Detroit, the Detroit Glider Club, the Detroit Glider School, the Mount Clemens Flying Club, the Eagle Rock Aircraft Co., and the Detroit Aircraft Corp.

S.A.E. Members Caught Out on a Fly

Representatives of the Society who, after mature deliberation, concluded to venture flight in a glider included President Edward P. Warner, Ralph Upson, aeronautical engineer, Red Bank, N. J., and A. J. Underwood, director of aeronautic activities for the Society. The accompanying illustrations show President Warner and Mr. Underwood as they were about to take off in gliders of different type but, perhaps fortunately, each of these gliders was speedier than the photographers and no pictures of the landing of these machines and their occupants are available. The two small illustrations indicate the character of the field and show some of the individuals who represented the audience.

Inspection Trip Affords Outing

SPECIAL arrangements, made for traveling by motorcoach, Thursday, April 10, enabled members and guests of the Society who so desired to inspect manufacturing processes at the Ford Motor Co. plant, to visit the Ford airport and the airplane factory, and to view the 125-acre village of Greenfield, to which buildings comprising an historic presentation of American architecture and development have been transferred by its owner for preservation.

It is impossible to give in a brief article a description of the wonderful automobile plant visited by the party; but some idea of its vast size and unique features is already possessed by those who have been fortunate enough to visit it, and others have seen articles which have appeared in the various trade periodicals from time to time. For those who are specially interested in the history of this plant, reference is made to a paper entitled Ford Engine-Cylinder Production, by P. E. Haglund and I. B. Scofield, which was published in THE JOURNAL, December, 1922, beginning on p. 463.

Luncheon Served; Ford Village Visited

Following luncheon at the Administration Building, the visitors were conveyed to the Ford Historical Village, where those in attendance visited with especial interest the original Edison Laboratory and the old Clinton Inn, shown in the accompanying illustrations, as well as the old post office, where post cards illustrating the different buildings in the village were available.

The Inn contains a most unusual collection of various kinds of antiques, in addition to the attractions afforded by the old-time architectural and decorative features of the building itself. An antique fireplace equipped with fire-

HISTORICAL BUILDINGS AT GREENFIELD, MICH.

Thomas A. Edison's Laboratory (Lower Left) and Its Interior (Upper View), Which Were Transferred from Menlo Park, N. J. The Old Clinton Inn (Lower Right), Contains a Most Interesting and Valuable Collection of Antiques of Many Kinds as Well as Being Most Attractive from an Architectural and Historical Viewpoint

tending implements, cooking utensils suited to fireplace usage, a long-handled copper "warming-pan," and other old-fashioned objects too numerous to mention, indicate the character of the collection so far as one portion of it is concerned. For the information of those who desire it, the bar is at the left as one enters; but this, also, is old-fashioned.

The Museum, the Church and the other buildings in the Village were somewhat slighted, in that time did not permit the guests to give them all the attention they deserve.

Activities at Ford Airport

At the Ford Airport the visitors were shown through the airplane factory. Thus they were enabled to see Ford tri-motored planes in process of construction on the production line. Guides were assigned to explain the methods of production and to direct the attention of the various members of the several groups of visitors toward special features of interest.

Among the other attractions at the Airport were the departure of one of the regular passenger-planes for Cleveland and the several take-offs of tri-motored planes for commercial flights over Detroit and its environs. The Airport station and the accommodations provided for passengers for prospective flights were observed to be most carefully thought out and well designed to satisfy the patrons.

Society to Celebrate Silver Anniversary

(*Concluded from p.* 532)

General Motors Corp., and Lieut. C. B. Harper, of the Bureau of Aeronautics, will talk on aircraft problems. For the Research Session, scheduled for the same hour, the following papers have been prepared: Engine Acceleration, by C. S. Bruce, of the Bureau of Standards; Effect of Weathering in the Tank on the Vapor-Locking Tendency of Gasolines, by O. C. Bridgeman and E. W. Aldrich, of the Bureau of Standards; and Vapor Lock, by W. C. Bauer, of the Standard Oil Co.

Afternoons Free for Recreation

No technical sessions will be held on any afternoon of the Summer Meeting. Monday and Thursday afternoons will be kept open for any recreational activities to which the individual tastes of the members lead them. Golf will be the only organized sport, although equipment for tennis and archery will be available for any members who desire to make use of it. A bridge party will be given for the ladies on each morning and on Monday afternoon.

A Field Day, of humorous character, similar to the Field Day at the 1929 Summer Meeting, will be staged on Tuesday afternoon.

Plans for Anniversary Pageant

Wednesday afternoon will be devoted to an exhibition and pageant celebrating the 25th anniversary of the founding of the Society.

More than 1200 automotive engineers and executives are expected to be present, including scores of prominent officials who can claim association with the motor-vehicle industry since the early nineties. Others who have been out of the business for years are planning to come to the reunion. Among the several hundred exhibits will be contributions loaned by the Smithsonian Institution, including the Manly aeronautical engine, several models of early internal-combustion engines; the famous "999" racer and other museum pieces loaned by Henry Ford; a number of round-the-world cars, old steam cars, automobiles of "ancient vintage" from a dozen factories of the early years of the century.

Thirty French engineers representing the Societé des Ingenieurs de l'Automobile will be present. A number of Government officials from the Department of Commerce and the Bureau of Standards, and representatives of the Army and Navy and of the various automotive and aeronautical associations have signified their intention to be present.

A caravan of motorized soldiery from Camp Holabird under the command of Col. Edgar S. Stayer has altered its itinerary so as to be present for three days of the meeting and will bring the historic limousine which General Pershing used at the front in the World War and a number of other interesting vehicles, including a complete electric-light plant and a field kitchen on wheels. Diesel-engined vehicles will also be shown.

Special Trains to Meeting

THE railroads have granted 1½-fare rates for tickets to the meeting and return, and special trains will be run as follows:

To French Lick

BY NEW YORK CENTRAL AND MICHIGAN CENTRAL RAILROADS

Leave		
New York City	May 24, 2:10 p.m.	(E.S.T.)
Buffalo	May 24, 11:10 p.m.[1]	(E.S.T.)
Cleveland	May 25, 2:55 a.m.[1]	(E.S.T.)
Indianapolis	May 25, 8:30 a.m.	(C.S.T.)
Arrive		
French Lick	May 25, 12:00 noon	(C.S.T.)
Leave		
Detroit	May 24, 8:00 p.m.	(E.S.T.)
Arrive		
French Lick	May 25, 7:00 a.m.	(C.S.T.)

[1] Cars will be ready for occupancy at 10:00 p. m.

Returning from French Lick

BY NEW YORK CENTRAL AND MICHIGAN CENTRAL

Leave		
French Lick	May 29, 6:30 p.m.	(C.S.T.)
Arrive		
Detroit	May 30, 8:00 a.m.	(E.S.T.)
Cleveland	May 30, 5:30 a.m.	(E.S.T.)
Buffalo	May 30, 9:05 a.m.	(E.S.T.)
New York City	May 30, 6:50 p.m.	(E.S.T.)

The French Lick Springs Hotel will serve breakfast to passengers arriving from Detroit at 7:00 a. m., luncheon to those arriving from New York City, Buffalo, Cleveland and Indianapolis at noon, and supper to passengers leaving on the trains at 6:30 p. m.

For the accommodation of those who desire to attend the Indianapolis races on May 30, special cars will leave French Lick in the evening of the 29th and be switched to the Prest-O-Lite siding near the race track early on the morning of the races. Immediately after the races, the cars will be moved to the Union Station and attached to the Detroit train leaving Indianapolis at 11:00 p. m., arriving in Detroit at 8:10 a. m., May 31.

Members returning to other cities must change trains at Indianapolis.

Requests for Pullman reservations going to the meeting should be addressed immediately, accompanied by check, to

Detroit—Mrs. B. Brede, 2-136 General Motors Building.

New York City—Miss J. A. McCormick, 29 West 39th Street.

Buffalo—Mr. W. E. John, 1280 Niagara Street.

Cleveland—Mr. B. H. Blair, 6500 Central Avenue.

The one-way Pullman charges are as follows:

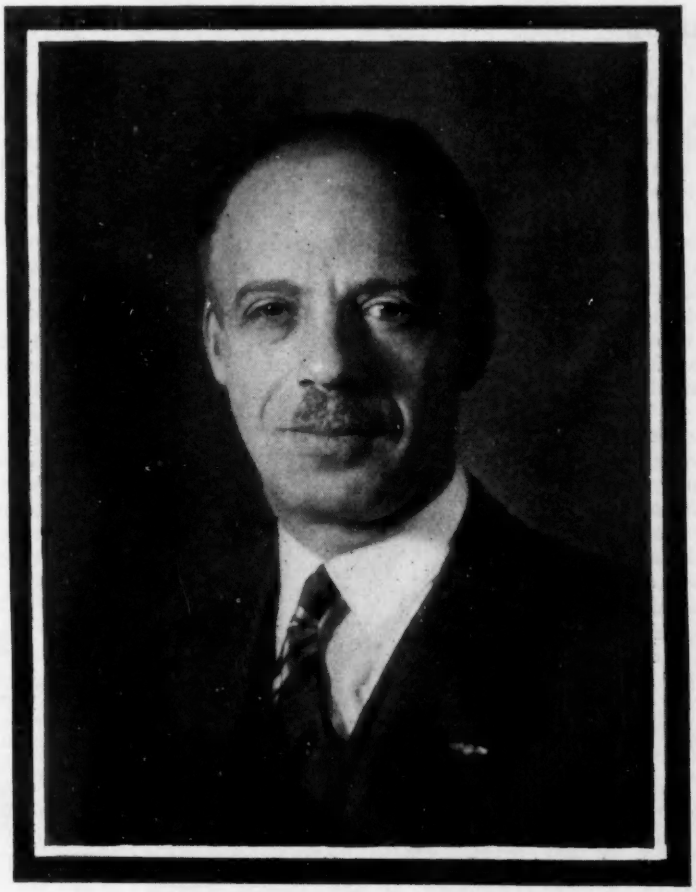
From	Lower	Upper	Compartment	Drawing-Room
New York City	$9.00	$7.20	$25.50	$31.50
Buffalo	7.50	6.00	21.00	27.00
Cleveland	5.25	4.20	15.00	19.50
Detroit	4.50	3.60	12.75	16.50

Fare-and-a-half railroad tickets should be purchased at local ticket offices.

Lionel M. Woolson

TO EVERYONE connected with the aeronautic and automobile industries and particularly to those who knew him personally, the reports of the accident that resulted in the sacrifice of Capt. L. M. Woolson on April 23 to the development of aviation came as a great shock. Not only is the loss of so highly competent a research and design engineer at the very height of his career most deeply deplored as irreparable to the industry, but the grief of his many personal friends and acquaintances is as poignant as if Captain Woolson had been a member of their families. For he was beloved of them all for his amiability and many other admirable qualities of character as well as vastly esteemed for his marked ability as an experimental engineer of many noteworthy accomplishments.

Taken at the age of only 42 years and the victim of his great enthusiasm, untiring energy and unfailing courage in the development of aeronautic engines, the sorrow caused by Captain Woolson's untimely end is assuaged only by the thought that he had lived to see his most recent experiment work brought to a state of success widely acclaimed as the most outstanding development of the Diesel engine for aircraft use. Even in the accident that claimed its three victims in the crash in a snowstorm at Attica, N. Y., of the Diesel-engined airplane that was being flown from Detroit to New York City for exhibition in the National Airplane Show this month, Captain Woolson's great contribution to greater aircraft safety was demonstrated, in that the airplane did not take fire and burn. This freedom from a hazard that has claimed many victims has been the factor which this ardent advocate of the oil engine had consistently asserted to be its most important advantage. But what a pity that proof of it should have to come in such a deplorable way.



LIONEL M. WOOLSON

Exceedingly few men have done so much to advance the motor-vehicle and the aeronautic industries in the quarter century of their greatest development as had Captain Woolson, or been such active, helpful and loyal workers in the activities of the Society. Virtually all of his life since his graduation from the classic and science courses at St. Paul's School in London, England, in 1905 was was devoted to the automotive industry in this Country, the last 11 years in the service of the Packard Motor Car Co. Among his notable achievements in engine design were the Packard Diesel 9-cylinder air-cooled radial engine, a number of aircraft engines designed for the Navy, two 24-cylinder water-cooled racing engines designed for use in the seaplanes designed by Lieut. Alford J. Williams for competition in the Schneider Cup Race, engines used in the American-built airship Shenandoah, the one used by Commander John Rogers on his airplane flight to Honolulu, and the engines used in Gar Wood's hydroplane entries for the Harmsworth Cup.

Captain Woolson's history shows that he was born at Los Angeles in June, 1888, and spent most of his youth there and in Seattle, Wash. Later his parents moved to England, and he completed his scholastic education in London at St. Paul's School. Returning to the United States in 1905, he started his industrial career as stock-keeper in charge of Mercedes spare parts for Allen Halle & Co. in New York City. The following year found him in charge of blueprint records for the Western Electric Co., and in 1907 he was assistant engineer for Ford, Bacon & Davis, also in New York City, doing surveying and map making. For ten years thereafter he was successively foreman of the West End Garage in West End, N. J., in charge of automotive repairing and experimental work, and mechanical engineer for the Bijur Motor Lighting Co., in Hoboken, N. J., engaged in designing starting and lighting installations. The years 1917 and 1918 were devoted to the United States Air Service during the war, when he had charge of engine testing at McCook Field, at Dayton, Ohio. For the 11 years since leaving active service for the Army Air Service, Captain Woolson devoted all his energies in research and experimental work to the Packard interests, first in charge of laboratory tests, then as experimental engineer and, beginning in 1923, as aeronautical and research engineer.

Elected a Member of the Society in December, 1919, Captain Woolson served successively as a member of the Aeronautic Division of the Standards Committee from 1922 to 1925, a member of the Engine Division of the Standards Committee in 1926, Second Vice-President representing aviation engineering in 1928, Chairman of the Aircraft-Engine Division of the Standards Committee and a member of the Stock-Car-Contest Advisory Committee in 1929, and this year a member of the Aircraft-Engine Committee, the Diesel-Engine Committee, the Research Committee, the Fuels Subcommittee of the Research Committee, the Aircraft Engine Division of the Standards Committee, and of the Stock-Car-Contest Advisory Committee. He also somehow found time to serve as Vice-Chairman of the Detroit Section in 1925, as Chairman of the Section in 1926, and as Chairman of the Aeronautic Division of the Section in 1928.

As if all the foregoing activities were not enough to absorb the energies of this indefatigable worker, Captain Woolson presented at meetings of the Society the following papers: The

Packard Fuelizer, published in THE JOURNAL in March, 1921, p. 240, and in TRANSACTIONS for 1921, p. 678; Recent Developments in Aircraft Engines, published in THE JOURNAL in March, 1925, p. 297, and in TRANSACTIONS for that year, p. 617; The Packard X-24-Cylinder 1500-Hp. Water-Cooled Aircraft Engine, published in the S.A.E. JOURNAL for July, 1928, p. 68, and in TRANSACTIONS for that year, p. 493; Diesel Engines for Aircraft, published in the S.A.E. JOURNAL, February, 1929, p. 173; Air and Ground Transportation Compared, published in the S.A.E. JOURNAL, June, 1929, p. 575; and The Packard Diesel Aircraft Engine, published in the S.A.E. JOURNAL, April, p. 431.

Clearton H. Reynolds

AS A result of injuries sustained by him in an automobile accident a short distance from the main gate of Selfridge Field, Mt. Clemens, Mich., where he was commanding the 15th squadron, United States Army Air Corps, Capt. Clearton H. Reynolds passed away early on the morning of Feb. 15.

Born at Provincetown, Mass., in 1888, and educated in chemistry, physics and mechanical engineering at New Hampshire State College and Dartmouth College, from whence he obtained his degree of Bachelor of Science in June, 1912, Captain Reynolds was for several years assistant instructor of physics at Dartmouth College. June 1, 1916, found him in the Aviation Section of the Army. His posts were varied, as he was stationed successively at Mineola, N. Y.; Langley Field, Va.; Bolling Field, Anacostia, D. C., and last at Mount Clemens, Mich. He was elected a Service Member of the Society in 1920.

John J. Amory

THE SUDDEN and lamented death of John J. Amory in New York City on Feb. 27 after an operation, closed the varied and picturesque career of a well known man in the motorboat industry.

Mr. Amory had been chairman of the show committee of the Jubilee Motorboat Show recently held at the Grand Central Palace. He was born in Fond du Lac, Wis., in July, 1856. After receiving a general education at the schools there, he completed his scholastic work at Riverview College, Poughkeepsie, N. Y., and returned to Fond du Lac to enter employment as a clerk in a railroad office. The next year found him at Santa Monica, Calif., and later at Tucson, Ariz., earning his living as a liveryman; then within a few years he was successively a miner in Tombstone, Ariz., an express-company agent in Texarkana, Ark., and a hotel proprietor in Billings, Mont. His next commercial endeavor was far removed from such as these, being that of secretary and treasurer of the Armstrong Mfg. Co., in Bridgeport, Conn. About 1886 he joined the Gas Engine & Power Co., of New York City, in the same capacity. Subsequently this company was merged with Charles L. Seabury & Co., and became known as the Consolidated Shipbuilding Corp. At the time of his death, Mr. Amory was president of the latter corporation, a position he had held for many years.

Mr. Amory was elected as Associate Member of the Society in April, 1917, and was transferred to the grade of Member in July, 1918. During the year 1919 he was Second Vice-President of the Society representing Marine Engineering and also a member of the Marine Division of the Standards Committee. In 1927 he was elected first vice-president of the National Association of Engine and Boat Manufacturers, Inc., and served as such and as a member of its executive committee up to the time of his death. He was also a member of the Society of Naval Architects, the Marine Engineers, and several social and sport clubs.

Col. William Turnbull

THE automotive industry lost one of its veterans and the Society one of its valued Members with the passing of Col. William Turnbull on Feb. 9 as the result of a heart attack, after having been ill for more than a week.

Born in Kirkconnell, Scotland, in 1873, Mr. Turnbull came to this Country at an early age and attended school at Dover, Ill., where his family had settled. It was at Danville, Ill., however, that he received the rudiments of his life work as a mechanical engineer in the employment of the Danville Foundry & Machinery Co. His hobby was bicycle racing, and after F. F. Ide, then president of a bicycle factory in Peoria, had asked him to ride for him and gave him employment at the Ide factory, the youth gained considerable fame as a professional bicycle rider. Later on he secured a position as pattern-maker at the Toledo, Peoria & Western Railroad shops, where he remained for three years.

With the advent of the automobile, Mr. Turnbull became interested in its development and exploitation, and it was not unnatural that he should have been the man to open the first garage pattern-shop and automobile salesroom in Peoria, which occurred in May, 1902. Failing health forced him to give up the garage, however, and with his family he returned to the home of his birth. Upon his return to Peoria in 1911, he joined the forces of the Holt Mfg. Co. as engineer. He was superintendent of the company for three years, and then was made chief engineer of that company. When, in 1926, the Caterpillar Tractor Co. succeeded the Holt Mfg. Co., Mr. Turnbull retained his position as chief engineer. He was well known as having aided materially in the design of caterpillar tractors, such as are now in use, and is credited with having designed a small tractor that functioned satisfactorily 90 days after he was asked to aid in designing such a machine.

Colonel Turnbull was made a lieutenant colonel in the Ordnance Department in 1928 as a member of the National Ordnance Advisory Board, and was an alternate on the Ordnance Advisory Committee of the Society. Colonel Turnbull was elected to Membership in the Society in 1919.

Brainerd F. Phillipson

BRAINERD F. PHILLIPSON, president of the Climax Molybdenum Co., of New York City, and a Member of the Society since 1920, passed away on April 7.

Mr. Phillipson was born in Chicago on March 24, 1890, and received his technical training in the School of Mines at Columbia University, graduating with the degree of Chemical Engineer in 1913. In November, 1913, he entered the employment of the American Metal Co., of New York City, as assistant manager of the ore department and remained with that company for six years. In 1919, the Climax Molybdenum Co. was formed, with Mr. Phillipson as its president, a position which he held until his recent death.

Mr. Phillipson was elected a Member of the Society in 1920 and a Member of the Metropolitan Section in 1922.

Russell Huff

A VETERAN of the automotive industry and an active, long-time member of the Society was lost when Russell Huff, a Past President of the Society, passed away in St. Petersburg, Fla., on March 26, following a period of ill health.

Born at Leesburg, Ohio, on Oct. 21, 1877, Mr. Huff received his technical education at the Case School of Applied Science in Cleveland, and after his graduation from there in June, 1900, he joined the Packard Motor Car Co., of Detroit. He remained with this company for 15 years, during which time he rose to the position of chief engineer and later became consulting engineer. In 1916 he became a consulting engineer for Dodge Brothers, of Detroit, and held this position until 1925, when he was made director of engineering there. Failing health forced him to resign, however, and he finally went to reside at his summer home in St. Petersburg last year. His death is greatly deplored by all who knew him.

Mr. Huff had been very active in the

Society. He became a Member in 1907 and a few years later was appointed a member of the Committee on Electrical Equipment and its Subcommittee on Investigation of the Merits of Grounded versus Two-Wire Systems. He held a place on this committee from 1912 to 1916, when he was elected to the Presidency of the Society. In 1922 he was appointed to membership on the Finance Committee. He was the author of a paper on Factors of Safety, which was published in the BULLETIN for July, 1916, p. 475, and TRANSACTIONS for 1916, vol. 2, p. 70. He was for many year also a member of the Detroit Section.

Frederick V. McGraw

INJURIES in an automobile accident on April 12 resulted in the death, two days later, of Fred V. McGraw, sales manager of the Ray Day Piston Co., Detroit, in the Mount Carmel Hospital at Columbus, Ohio. The accident was caused by another car turning out of the line coming toward the car in which Mr. McGraw was riding and striking it head on, causing it to turn over in a ditch.

Mr. McGraw was born August 30, 1888, in San Francisco, and received his early education at the Belmont Preparatory School. He was for a year a student at the University of California, where he studied mining engineering. After leaving college, in 1908, his work was almost entirely selling and rendering field service. For years he operated as a manufacturer's agent, and between the years of 1908 and 1920 represented the following companies: Vlchek Tool Co., of Cleveland; Packard Electric Co., Warren, Ohio; Metal Stamping Co., Long Island City, N. Y.; Black & Decker Mfg. Co., Towson, Md.; Husky Wrench Co., Milwaukee; and the Multibestos Co., Walpole, Mass.

For three years Mr. McGraw was connected with the Mallory Electric Corp., of Toledo, Ohio, engaged in selling service in the field as well as giving talks on ignition and on pistons at meetings of mechanics and salesmen. He then joined the Ray Day Piston Co. and served in the capacity of sales engineer up to the time of his sudden demise.

Mr. McGraw had been an Associate Member of the Society since 1929. He was also a Member of the Detroit Section.

Edwin Hoyt Lockwood

THE death from heart disease of Prof. E. H. Lockwood, who was Higgins professor of mechanical engineering in Sheffield Scientific School of Yale University, on April 16 removed one of America's best-known authorities on the utilization of fuels in internal-combustion engines.

Born at New Canaan, Conn., Oct. 31, 1866, Prof. Lockwood was educated at Sheffield Scientific School, where he pursued a course in mechanical engineering. He received a degree of Mechanical Engineer in 1892 and a degree of Doctor of Philosophy in 1901. He was employed during the summer vacations as draftsman and designer of special machinery by the Diamond Match Co. in 1888 and 1889, on steam engines and air compressors by the Southwork Foundry & Machine Co. in 1895 and by the Deane Steam Pump Co. in 1901.

In 1890 Professor Lockwood became an instructor in Sheffield Scientific School, where he taught mechanical drawing, and later became assistant professor of mechanical engineering. In 1913 he was put in charge of the experimental laboratory of steam and gas engineering; in 1924 he was made an associate professor, and in 1927 he was appointed Higgins professor of mechanical engineering. During his long career on the Yale faculty he taught nearly every subject in mechanical engineering, and had become known throughout the Country for his important investigations on fuel combustion in power and heating and in automotive engineering.

Professor Lockwood was elected a Member of the Society in 1919, and since 1926 had been a member of the Research Committee of the Society as well as a member of the Riding-Qualities Subcommittee and the Highway Subcommittee. He was also affiliated with many other engineering organizations.

Papers written by Professor Lockwood and presented individually or in collaboration with others before the S.A.E. are as follows: The Practical Testing of Motor-Vehicles, which appeared in TRANSACTINS for 1915, vol. 1, p. 68; Power Losses in Pneumatic Tires, printed in the BULLETIN, February, 1917, p. 581, and in TRANSACTIONS for 1917, vol. 1, p. 377; Chassis Friction Losses, published in THE JOURNAL, November, 1922, p. 415, and reprinted in TRANSACTIONS for 1922, vol. 2, p. 384; A New Interpretation of Exhaust-Gas Analysis, published in THE JOURNAL, March, 1923, p. 299; Cooling Capacity of Automotive Radiators, published in THE JOURNAL, January, 1923, p. 57, and in TRANSACTIONS for 1923, vol. 1, p. 331; A Riding-Quality Indicator, published in THE JOURNAL, July, 1924, p. 40; Exhaust-Gas-Analysis Calculations, published in THE JOURNAL, November, 1927, p. 571, and in TRANSACTIONS for that year, vol. 2, p. 21; Legislation on Automobile Brakes, published in the S.A.E. JOURNAL, August, 1928, p. 137; and Exhaust - Gas - Analysis. Calculations, published in the S.A.E. JOURNAL, September, 1928, p. 314.

John D. Cutter

A LIFE of well-rendered service and gratifying achievement came to a close on March 11, when John D. Cutter, manager of the shackle division of the Fafnir Bearing Co., of New Britain, Conn., passed away.

Mr. Cutter was born in Orange, N. J., on Oct. 31, 1885. He received a general education and graduated from Stevens Institute with the degree of Mechanical Engineer in 1910. He thereupon accepted his first position with the Billings & Spencer Co., of Hartford, Conn., which he served for two years as assistant foreman and head of the treating department. Various posts were then held by him in the metallurgical departments of several Hartford firms, until, in April, 1919, he became field metallurgist for the Crucible Steel Co. of America. In 1921 he joined the Climax Molybdenum Co., of New York City, as metallurgist, and the following year was made vice-president of that company. He held this post until 1928, when he was made sales engineer for the Fafnir Bearing Co., with offices in Detroit. The next year he was advanced to the post of manager of the shackle division at the company's plant in New Britain, a position he held until the time of his death.

Mr. Cutter became a Member of the Society in September, 1919. At various times he was a member of the Mid-West Section, Metropolitan and Detroit Sections of the Society. He was appointed a member of the Iron and Steel Division of the Standards Committee in 1926 and served on this Division until his death.

Applicants Qualified

The following applicants have qualified for admission to the Society between March 10 and April 10, 1930. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff.) Affiliate; (S M) Service Member; (F M) Foreign Member.

ABRAMS, JESS (J) draftsman, engineering department, American Chain Co., *Bridgeport, Conn.*

ANDERSON, CLAY (A) commercial car and truck representative, Dodge Brothers Corp., 250 West 57th Street, *New York City.*

ANGELL, CHESTER M. (M) vice-president in charge of production, Vesta Battery Corp., 6501 West 65th Street, *Chicago.*

AUG, WILLIAM F. (J) airplane design, Keystone-Loening Aeronautical Corp., 31st Street and East River, New York City; (mail) 446 Bement Avenue, *West New Brighton, Staten Island, N. Y.*

BERKOW, MURRAY (J) stress analysis department, Bellanca Aircraft Corp., *New Castle, Del.;* (mail) 151 East Second Street.

BOCK, KARL W. (A) division bus manager, western district, Mack-International Motor Truck Corp., 2752 Farnam Street, Box 1052, *Omaha, Neb.*

BOYNTON, FREDERICK L. (J) corresponds to general manager, Estate of Elmer E. Boynton, 307 North Main Street, *Sycamore, Ill.*

BRIDGEMAN, OSCAR C. (S M) research associate, Bureau of Standards, *City of Washington.*

BROWN, GIBSON W. (M) superintendent of motor-vehicles, Bell Telephone Co. of Pennsylvania, 416 Seventh Avenue, *Pittsburgh.*

BROWNELL, J. L. (M) consulting engineer, Checker Cab Mfg. Corp., *Kalamazoo, Mich.;* (mail) 2328 Oakland Drive.

CABENA, HAROLD (A) service manager, Queen's Bridge Motors, Proprietary, Ltd., Queen's Bridge Square, *South Melbourne, Australia.*

CHANG, SIH-VAN (J) student engineer, General Railway Signal Co., West Avenue, *Rochester, N. Y.;* (mail) Central Y. M. C. A.

CLIFFE, FRED (F M) chief designer, Laycock Engineering Co., Ltd., *Sheffield, England;* (mail) Modwena, The Grove, Heatherfield, Totley, North.

COATES, J. EDWIN (J) propeller engineer, Hamilton Standard Propeller Corp., Homestead, Pa.; (mail) 4903 Baum Boulevard, *Pittsburgh.*

CORPE, THOMAS HENRY (A) representative, in charge of European operations, General Motors Export Co., 136 Avenue des Champs Elysees, *Paris, 8, France.*

DEAN, SHIRLEY FAXON (A) service-promotion traveller, Buick Motor Co. of New York, 1733 Broadway, *New York City;* (mail) 57 to 63 Wadsworth Terrace.

DENNINGER, ELBERT (J) student engineer, Mack Brothers Motor Car Co., *Allentown, Pa.;* (mail) 104 North 13th Street.

DIMMITT, ROBERT WILLIAM (F M) transport superintendent, Melbourne Electric Supply Co., *Melbourne, Victoria, Australia.*

DORR, LEONARD ANTHONY (J) engineer, Department of Street Railways, *Detroit;* (mail) 4815 Baldwin Avenue.

ESHBAUGH, JESSE E. (M) research and experimental engineer, A. C. Spark Plug Co., *Flint, Mich.;* (mail) 1713 Supont Street.

EVERITT, FREDERICK H. (J) time study, National Twist Drill & Tool Co., 6522 Brush Street, *Detroit;* (mail) Y. M. C. A., Grand Circus Park.

GRAVES, BENJAMIN P. (M) chief engineer, Brown & Sharpe Mfg. Co., *Providence, R. I.*

GREENEBAUM, LEON C. (J) vice-president, Metropolitan Distributors, Inc., 501 Tenth Avenue at 38th Street, *New York City.*

HANFLAND, CURT (F M) production engineer, General Motors G.m.b.h., Berlin, Borsigwalde, Germany; (mail) *Berlin W. 62, Bayreutherstr. 7, Germany.*

HOBBS, W. T. (A) president, Hobbs Mfg. Co., 605 North Main Street, *Fort Worth, Texas.*

HOLLINGER, HAROLD D. (M) assistant general superintendent, plant 18 and 20, Ternstedt Mfg. Co., 6307 West Fort Street, *Detroit;* (mail) 760 Campbell Avenue, Apartment 204.

HUTCHENREUTHER, LOUIS (A) supervisor of quality, contact representative, Federal Mogul Corp., 11031 Shoemaker, *Detroit;* (mail) 15905 Evanston Avenue.

HUTCHINS, GEORGE A. (M) superintendent, engine division, White Motor Co., Cleveland; (mail) 4494 Rainbow Road, *South Euclid, Ohio.*

KELLY, R. LLOYD (J) body engineer, General Motors of Canada, *Oshawa, Ont., Canada;* (mail) 610 Simcoe Street, North.

KNIGHT, HOWARD M. (M) assistant experimental engineer, Hupp Motor Car Corp., 3641 East Milwaukee, *Detroit;* (mail) 14988 Rossini Drive.

LEXOW, FREDERIC R. (A) service manager, Marmon Automobile Co. of New York, *Brooklyn, N. Y.;* (mail) 100 Lefferts Avenue.

LINDSTROM, OLOF (A) manager, commercial car division, General Motors Nordiska, A.B., Skanstull, *Stockholm 20, Sweden.*

LUCAS, LTD., JOSEPH (Aff.) Great King Street, *Birmingham, England;* Representative: Waring, A. B., secretary, treasurer.

MACK, HARLAND W. (A) branch manager, Simplex Piston Ring Co. of America, Inc., 519 19th Street, *Oakland, Calif.*

MAY, V. G. (J) body draftsman, Pierce-Arrow Motor Car Co., *Buffalo;* (mail) 777 Amherst Street.

MCGHAN, WILLIAM ADDISON (A) National Air Transport, Inc., *Chicago;* (mail) 6212 South Troy Street.

MCGUIRE, R. M. (A) vice-president in charge of sales, Micromatic Hone Corp., 5057 Woodward Avenue, *Detroit.*

O'BRIEN, JOHN J. (A) president, general manager, Motor & Plane Accessories, Inc., 719 Fisher Building, *Detroit.*

POLO, J. B. (M) designing, laying out, detailing, Waukesha Motor Co., *Waukesha, Wis.;* (mail) 540 West College Avenue.

RUEHL, ERWIN F. (M) assistant chief engineer, oil engine department, I. P. Morris & de LaVergne, Inc., Richmond and Norris Streets, *Philadelphia;* (mail) 7503 Germantown Avenue.

SCHULTZ, ARTHUR B. (J) chief engineer, Hise Aircraft Corp., 5625 St. Clair, *Detroit.*

SHOEMAKER, JAMES MARSHALL, Lieut.-Commander (S M) head of powerplant-design section, Bureau of Aeronautics, Navy Department, *City of Washington.*

SIEGER, GEORGE N. (M) technical adviser to president, Carboloy Co., Inc., 350 Madison Avenue, *New York City.*

SIKORSKY, IGOR I. (M) vice-president in charge of engineering, Sikorsky Aviation Corp., *Bridgeport, Conn.*

SIRRINE, EARL D. (M) transportation engineer, Autocar Co., *Ardmore, Pa.;* (mail) 631 Valley View Road.

SLIFER, W. J. (M) president, W. J. Slifer & Co., *Easton, Pa.*

SNADER, IRA J. (M) production engineer, Wright Aeronautical Corp., *Paterson, N. J.*

STILES, ROGER S. (A) technical data section, head, service department, General Motors Japan, Ltd., Osaka, Japan; (mail) 3 South Mountain Terrace, *Montclair, N. J.*

THOMPSON, J. ARTHUR (M) president, Gladacres, Inc., *Rushville, Ill.*

TOWNSLEY, ROBERT E. (S M) inspector, motor-vehicles and spare parts, United States Army, Quartermaster Corps, Holabird Quartermaster Depot, *Baltimore.*

VANCE, ARLYN H. (M) Stromberg Motor Devices Co., *Chicago;* (mail) 354 West 65th Street.

WARNER, CLINTON PHILIP (A) service manager, Consolidated Aircraft Corp., 2050 Elmwood Avenue, *Buffalo.*

WHELAN, CHARLES M. (A) local sales manager, Aluminum Co. of America, Pittsburgh; (mail) 3311 Dunn Road, *Detroit.*

WOLLNER, HANS (M) tool engineer, Graham-Paige Motor Car Corp., West Warren Avenue, *Detroit;* (mail) 6750 Clifton Avenue.

Council Action at April Meeting

AT a meeting of the Council held in Detroit on April 21 the following were present: President Warner, Past-Presidents Strickland and Wall, Vice-Presidents Treiber, McCain, Scaife, Davis and Younger, Councilors Fishleigh, Teetor and Parker, Treasurer Whittelsey and Chairman Lemon, of the Sections Committee.

A financial statement as of March 31, 1930, showed a net balance of assets over liabilities of $242,051.87, this being $30,993.49 more than the corresponding figure on the same day of 1929. The gross income of the Society for the first six months of the fiscal year amounted to $216,954.05, the operating expense being $204,667.04. The income for the month of March was $40,862.27, and the operating expense during the same month was $44,212.05.

Sixty-one applications for individual membership and 7 transfers in grade of membership were approved. Three reinstatements were made, 10 applications reapproved and 5 resignations accepted. Eighty-three applications for individual membership, 3 grade transfers and 2 reinstatements on which the Council had acted by mail vote were approved.

The Council approved including advertising of complete vehicles in the June, 1930, issue of the S.A.E. JOURNAL, which is to be the 25th Anniversary Number.

Dr. H. C. Dickinson was named as the Society delegate at the International Conferences on Standardization to be held in Milan and Paris.

Applicants for Membership

The applications for membership received between March 15 and April 15, 1930, are listed below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

ADAMS, CHARLES P., tool engineer, Amtorg Trading Co., *New York City.*

ALBRIGHT, WILLIAM E., chief clerk, Philadelphia Gas Works Co., *Philadelphia.*

ALTOBELLIS, ANOCLETO CLIFFORD, tool engineering, New Process Gear Corp., *Syracuse, N. Y.*

ARNDT, J. W., secretary and general manager, Tide Water Lines, Inc., *Baltimore.*

ARRIGONI, FERDIE, president, Melrose Motors, Inc., The Bronx, *New York City.*

BARR, GEORGE MCQUEEN, in charge of engineering, Tallman Brass & Metal Co., *Hamilton, Ont., Canada.*

BARRY, E. DIGHTON, assistant field engineer, Pioneer Instrument Co., *Brooklyn, N. Y.*

BLACKFORD, JOHN M., manager, Detroit office, The Torrington Co., *Torrington, Conn.*

BLAYLOCK, RAYMOND C., aeronautical engineer, Curtiss Aeroplane & Motor Co., *Garden City, N. Y.*

BROOKS, M. P., superintendent of equipment, State of California, Division of Highways, *Sacramento, Calif.*

BULLARD, THEODORE H., director of engineering service, National Automotive Service, *San Francisco.*

BURT, GEORGE H., chief engineer, The Celotex Co., *Marrero, La.*

BYER, NATHAN, engineer, C. H. Matthiessen, Jr., *New York City.*

CALHOUN, THOMAS AUSTIN, manager of Duplate sales, Pittsburgh Plate Glass Co., Pittsburgh.

CARGO, FRANK, salesman, Bayerson Oil Works, *Erie, Pa.*

COE, ARTHUR B., vice-president, Fort Wayne Piston Service Co., Inc., *Fort Wayne, Ind.*

CRIST, LESTER R., draftsman, Lycoming Mfg. Co., *Williamsport, Pa.*

DAVIS, THOMAS A., service manager, Federal Motor Truck Co. of New York, *New York City.*

DEWAR, CHARLES E., superintendent, Champion Spark Plug Co., *Toledo, Ohio.*

DWIGHT, RALPH W., body engineer, Auburn Automobile Co., *Auburn, Ind.*

ELLIS, HERBERT, service manager, Lowas Garage, Inc., *Yonkers, N. Y.*

ELLIS, WILBER R., first lieutenant, United States Army, Coast Artillery Corps, Fort Monroe, Va., student at University of Michigan, *Ann Arbor, Mich.*

FARNWORTH, GEORGE J., metallurgist, Edward G. Budd Mfg. Co., *Detroit.*

FASSETT, LYLE A., service representative, Reo Motor Car Co., *Lansing, Mich.*

FERNLY, J. E., foreman shop and test departments, Packard, Inc., *Philadelphia.*

GARDNER, FRANK G., chief engineer, aircraft division, Breeze Corp., Inc., *Newark, N. J.*

GILLAN, PAUL L., engineer, passenger-car engine division, Lycoming Mfg. Co., *Williamsport, Pa.*

GROSSPETER, FRED WILLIAM, 140 Hillside Terrace, *Great Kills, Staten Island, N. Y.*

HAMILTON, WALTER A., chief engineer and vice-president, Aero Corp. of California, Inc., *Los Angeles.*

HARRIS, ARTHUR W., transmission engineer, Chevrolet Motor Ohio Co., *Toledo, Ohio.*

HAZZARD, HARRY I., draftsman, Lycoming Mfg. Co., *Williamsport, Pa.*

HENDERSON, GEORGE F., body-in-white engineer, H. H. Franklin Mfg. Co., *Syracuse, N. Y.*

HOERN, JOSEPH H., master mechanic, Wilcox Rich Corp., *Saginaw, Mich.*

HOUGH, WILLIAM JUSTUS, assistant general manager, Short Line Motor Freight, Inc., *Springfield, Mass.*

HOULT, WILLIAM H., superintendent of field tests, Chevrolet Motor Co., General Motors Proving Ground, *Milford, Mich.*

HUNT, LAWRENCE A., research engineer, Ethyl Gasoline Corp., *Yonkers, N. Y.*

JANES, ARTHUR R., president and general manager, Standard Foundry Co., *Racine, Wis.*

JENKINS, BURTON WRAY, service manager, J. F. O'Connor Sales Co., Inc., *Syracuse, N. Y.*

JOHNSON, E. D., experimental engineer, Wagner Electric Corp., *St. Louis.*

JONES, W. H., chief body draftsman, Lincoln Body Division, Ford Motor Co., *Dearborn, Mich.*

JOSLIN, LEON RAY, assistant research engineer, Standard Oil Development Co., *Linden, N. J.*

KIRK, WAYNE, assistant to the vice-president in charge of manufacturing, Pierce-Arrow Motor Car Co., *Buffalo.*

KUNKLE, B. D., president and general manager, Delco Products Corp., *Dayton, Ohio.*

LANDEFELD, WILLIAM, process engineer, H. H. Franklin Mfg. Co., *Syracuse, N. Y.*

LAWLER, FRANK P., consulting engineer, 251 Kearny St., *San Francisco.*

LEADEN, W. S., engineer to automotive industries, Anaconda Wire & Cable Co., *Detroit.*

LEWIS, EDWARD H., designing engineer, General Electric Co., *Bridgeport, Conn.*

LINDER, ALBERT, engineer, Chrysler Corp., *Highland Park, Mich.*

MALLOUF, NATHANIEL, president, Mallouf Haulage & Maintenance Corp., *New York City.*

MARTIN, EDWARD M., automobile experimental and research engineering, Locomobile Co. of America, Inc., *Bridgeport, Conn.*

MARTIN, LESLIE JOHN, superintendent, marine sales and engineering, Home Oil Distributors, Ltd., *Vancouver, B. C., Canada.*

MASTERSON, JOSEPH M., vocational instructor in gas-engine mechanics and automobile repairing, East New York Continuation School, *Brooklyn, N. Y.*

MCCAULEY, GEORGE H., automotive engineer, Standard Oil Co. of New Jersey, *Baltimore.*

MICHEL, CHRIS, engineer, Brown Lipe Gear Co., *Syracuse, N. Y.*

MICHLIN, MORRIS S., tool designer, H. H. Franklin Mfg. Co., *Syracuse, N. Y.*

MONAHAN, GORDON J., sales manager, Canadian Raybestos Co., Ltd., *Mimico, Ont., Canada.*

MONLUX, H. W., lubrication engineer, Richfield Oil Co., *Oakland, Calif.*

OLSON, GORDON C., associate editor, *Motive Power*, Gillette Publishing Co., *Chicago.*

OSMAN, RALPH T., dumptor department manager, National Equipment Corp., *Milwaukee.*

NEAVE, D. P. C., in charge of technical research, Morris Motors, Ltd., *Cowley, Oxford, England.*

NICHOLS, PROCTOR WALLACE, chief stress analyst, assistant chief engineer, Alexander Industries, *Colorado Springs, Col.*

PEDLER, WILFRED, assistant manager, French Motor Car Co., Ltd., *Bombay, India.*

PEW, WALTER CROCKER, district sales manager, *Sun Oil Co., Philadelphia.*

POPPE, E., works manager, Dennis Bros., Ltd., *Guilford, England.*

PORTER, GEORGE, superintendent of buildings, Packard Motor Car Co. of Boston, *Boston.*

PRILL, PAUL E., chief engineer and superintendent, Stolper Steel Products Corp., *Milwaukee.*

ROBBINS, WALTER G., district manager, The Carboloy Co., Inc., *Detroit.*

ROSENKRANZ, J. A., president, National Automotive and Electrical School, *Los Angeles.*

ROWLANDS, THOMAS WILLIAM, tool and machine designer, General Motors of Canada, Ltd., *Oshawa, Ont., Canada.*

SCHILDHAUER, CLARENCE H., assistant to general manager, Dornier Co. of America, *New York City.*

SHUTTS, O. M., engine designer, Lycoming Mfg. Co., *Williamsport, Pa.*

SIMONS, OTMAR F., specification engineer, Gramm Motors, Inc., *Delphos, Ohio.*

SMITH, ROBERT MUNROE, manager, Canada Point Co., Ltd., *Toronto, Ont., Canada.*

SMITH, W. RICHMOND, Speehn Real Estate & Operating Co., *New York City.*

SNYDER, J. F., automotive engineer, Standard Oil Co. of New York, *Boston.*

STEWART, CHARLES R., development engineer, Firestone Tire & Rubber Co., *Los Angeles.*

TOWNSHEND, BAILEY, physicist, Johns-Manville, Inc., *Manville, N. J.*

TREFZ, WALTER, director of mechanics school, Universal Aviation School, Division of Aviation Corp., *St. Louis.*

TURNQUIST, CARL HAROLD, student instructor, Cass Technical High School, *Detroit.*

UNGERER, CORNELIUS JOHN, headquarters mechanical inspector, South African Railways and Harbours, *Johannesburg, South Africa.*

VAN SLYKE, H. F., detail and layout draftsman, American LaFrance & Foamite Corp., *Linesville, Pa.*

VAN CAMP, BENJAMIN T., manager motor-truck department, George A. Hormel & Co., *Austin, Minn.*

VINT, ROBERT, engineering, Fisher Body Corp., *Detroit.*

WEST, PRICE D., manager service records department, Auburn Aubomobile Co., *Auburn, Ind.*

WHEATON, ABRAM W., president, A. W. Wheaton Brass Works, *Newark, N. J.*

WHIPPLE, OLIVER B., service and parts manager, Sturgeon & Beck, *Tulare, Calif.*

WINHALL, ERIC HERBERT, chief draftsman and designer, Automotive Engineering Co., Ltd., The Green, *Twickenham, England.*

WILLIAMS, DUNCAN B., engineer, Carbide & Carbon Chemicals Corp., *New York City.*

WINSTON, A. W., experimental engineer, Dow Chemical Co., *Midland, Mich.*

Notes and Reviews

These items, which are prepared by the Research Department, give brief descriptions of technical books and articles on automotive subjects. As a general rule, no attempt is made to give an exhaustive review, the purpose being to indicate what of special interest to the automotive industry has been published.

The letters and numbers in brackets following the titles classify the articles into the following divisions and subdivisions: *Divisions*—A, Aircraft; B, Body; C, Chassis Parts; D, Education; E, Engines; F, Highways; G, Material; H, Miscellaneous; I, Motorboat; J, Motorcoach; K, Motor-Truck; L, Passenger Car; M, Tractor. *Subdivisions*—1, Design and Research; 2, Maintenance and Service; 3, Miscellaneous; 4, Operation; 5, Production; 6, Sales.

AIRCRAFT

The Daniel Guggenheim International Safe Aircraft Competition Final Report. Published by the Daniel Guggenheim Fund for the Promotion of Aeronautics, Inc., New York City, Jan. 31, 1930; 147 pp., illustrated. [A-1]

Although a number of trade papers have carried comprehensive accounts of the recent Guggenheim Safe Airplane Competition, many engineers will welcome this complete and official report of the entire event under one cover.

The booklet contains a list of the Competition personnel and the entries in the Competition and gives a general summary and several pages of comment with notes on the results from an aerodynamical standpoint. The methods used in conducting the tests are explained and detailed information on the calibration of instruments and equipment is included. Appendix I consists of excerpts from preliminary reports; Appendix II, descriptions of the airplanes; Appendix III, the rules of the Competition. The report is liberally illustrated with photographs of the competing airplanes and the instruments used.

For anyone desiring supplementary information reference to the Feb. 8 issue of *Aviation*, which contains several unique articles on the Competition, is suggested. One article by Prof. W. G. Brown, who acted as chief observer during the tests, explains the methods of testing and the way in which the Tanager reacted to them. Robert R. Osborn, designer for the Curtiss Aeroplane & Motor Co., has contributed to this issue a technical description and chronological discussion of the incorporation of the design features of the winning plane; while Edward P. Warner, editor of *Aviation*, describes the plane from the point of view of an unskilled pilot. A complete description of the Tanager, by T. P. Wright, chief engineer of the airplane division of the Curtiss company, is published in the May, 1930, issue of the S.A.E. Journal.

The Torsion of Members Having Sections Common in Aircraft Construction. By George W. Trayer and H. W. March. Report No. 334. Published by the National Advisory Committee for Aeronautics, City of Washington, 1930; 49 pp., illustrated. [A-1]

This report presents the results of investigations of the torsion of structural members undertaken by the Forest Products Laboratory.

Within recent years a great variety of approximate torsion formulas and drafting-room processes have been advocated. In some of these, especially those involving mathematical considerations, the results are extremely complex and are not generally intelligible to engineers. The principal object of the investigation was to determine by experiment and theoretical investigation how accurate the more common of these formulas are and on what assumptions they are founded, and, if none of the proposed methods proved to be reasonably accurate in practice, to produce simple, practical formulas from reasonably correct assumptions, backed by experiment. A second object was to collect in readily accessible form the more useful of known results for the more common sections.

This report reviews informally the fundamental theory of torsion and shows how the more common formulas are developed from it. Formulas for all the important solid sections that have yielded to mathematical treatment are listed. Then follows a discussion of the torsion of tubular rods, with formulas both rigorous and approximate.

The Effect of Reduction Gearing on Propeller-Body Interference as Shown by Full-Scale Wind-Tunnel Tests. By Fred E. Weick. Report No. 338. Published by the National Advisory Committee for Aeronautics, City of Washington, 1930; 21 pp., illustrated. [A-1]

Full-scale tests have been made in the propeller research tunnel of the National Advisory Committee for Aeronautics, on a 10-ft. 5-in. propeller on a geared J-5 engine and also on a similar 8-ft. 11-in. propeller on a direct-drive J-5 engine. Each propeller was tested at two different pitch-settings and with a large and a small fuselage. The investigation was made in such a manner that the propeller-body interference factors were isolated, and it was found that, considering this interference only, the geared propellers had an appreciable advantage in propulsive efficiency, due partly to the larger diameter of the propellers with respect to the bodies and partly to the fact that the geared propellers were located farther ahead of the engines and bodies.

The Effect of Wing-Tip Floating Ailerons on the Autorotation of a Monoplane Wing Model. By Montgomery Knight and Carl J. Wenzinger. Technical Note No. 336; 19 pp., 5 figures. [A-1]

Measurement of Profile Drag on an Airplane in Flight by the Momentum Method. Parts I and II. By Martin Schrenk. Translated from *Luftfahrtforschung*, May 18, 1928. Technical Memoranda Nos. 557 and 558. Total 76 pp., 61 figures. [A-1]

Ratier Metal Propeller with Pitch Variable in Flight. By Pierre Léglise. Translated from *L'Aéronautique*, December, 1929. Technical Memorandum No. 559; 9 pp., 10 figures. [A-1]

The above listed Technical Note and Technical Memoranda were issued in March and April, 1930, by the National Advisory Committee for Aeronautics, City of Washington.

Calibration Constant of Wright Field 5-Ft. Wind-Tunnel. Air Corps Information Circular, Vol. VII, No. 643; 17 pp., illustrated. [A-1]

Miscellaneous Collected Airplane Structural-Design Data, Formulas and Methods. Air Corps Information Circular, Vol. VII, No. 644; 9 pp., illustrated. [A-1]

Determination of the Elastic Axis and Natural Periods of Vibration of the Atlantic C-2A Monoplane Wing. Air Corps Information Circular, Vol. VII, No. 645; 10 pp., illustrated. [A-1]

Static Test and Determination of the Elastic Axis of the (Materiel Division) Improved Stressed-Skin-Type Glider Wing. Air Corps Information Circular, Vol. VII, No. 646; 5 pp., illustrated. [A-1]

The four Circulars listed above were published on March 1, 1930, by the chief of the Air Corps, City of Washington.

(*Continued on next left-hand page*)

Notes and Reviews

Continued

Airplanes at the Show. By Leslie E. Neville. Published in *Aviation*, March 1, 1930, p. 419. [A-1]

Refinement of detail rather than radical departure from conventional design standards was the keynote of the group of airplanes, engines and accessories exhibited at the National Aeronautical Exposition held at St. Louis in February, 1930, according to Mr. Neville, in his technical review of the show. The floating aileron embodied in the design of the Curtiss Tanager is noted as the most unusual departure from standard aerodynamic practice, it being the only airplane having both wing flaps and slots, while the Whittelsey Avian had slots alone.

The article analyzes the airplanes as a group and contains descriptions, photographs and drawings of the newer models. Tables give a comparison of the characteristics of the airplanes exhibited at St. Louis with those of the Cleveland show in August, 1929, and the Detroit show in April, 1929.

The engines and accessories are considered in an article in the March 8 issue of *Aviation* which is reviewed in these columns under the Engine section.

Technical Details of the Dornier X. Published in *Aviation*, Jan. 4, 1930, p. 4. [A-1]

International interest has been attracted by the Dornier Do-X flying-boat, the largest craft of its type in the world, recently completed and test-flown. The article is a translation and abstract of a paper delivered by Dr. C. Dornier in Germany. A full description of this flying-boat, written by Dr. Dornier, is published in the S.A.E. JOURNAL of May, 1930.

Building Zeppelins in the United States. Walter E. Burton. Published in *Aviation*, Feb. 22, 1930, p. 366. [A-3]

The construction and equipment of the ZRS-4 and ZRS-5 are the subjects of this article, which also includes a proposed plan for passenger accommodations inside the hull and diagrams showing the various arrangements of airship lifting-gas and fuel-gas cells.

Looking Ahead in Aviation Lighting. By C. E. Weitz in collaboration with L. C. Porter and D. C. Young. Bulletin 55. Published by the engineering department, National Lamp Works of the General Electric Co., Cleveland; October, 1929; 56 pp., illustrated. [A-4]

This pamphlet summarizes the part that light is already playing in the service of aviation and ventures predictions as to the requirements of airport lighting that are likely to be encountered in the future. The lighting of airways, landing-fields, airports and airplanes is discussed and the leaflet is abundantly illustrated with photographs and diagrams.

Report of the Municipal Airport Committee, City Officials' Division, American Road Builder's Association. Presented at the annual convention of the American Road Builders' Association, Atlantic City, N. J., January, 1930. [A-4]

This report contains three complete papers on airport planning, drainage and surfacing, respectively, and includes short summaries of four other papers presented at the convention on airport problems. Airport Planning, by Russell Shaw, considers site selection, layout, clearing and grading, drainage, surfacing, lighting, fire protection, housing and equipment, public accommodations, and revenue. C. A. Hogentogler and F. A. Robeson, of the United States Bureau of Public Roads, make a valuable contribution to the subject of airport drainage in their paper by that title, which includes a bibliography; and C. N. Conner, in his paper, Airport Surfaces, presents information on types of highway surfaces and their possible adequacy as airport surfaces.

(*Continued on next left-hand page*)

Notes and Reviews

Continued

The Design and Lighting of Airports. By L. A. S. Wood. Paper presented at the convention of the American Society for Municipal Improvement, Philadelphia, October, 1929. [A-4]

The author stresses the advantages to a city of owning a well-designed and well-equipped airport and considers briefly the problems of selecting the site and designing and constructing the airport. The second part of the paper is devoted to a consideration of airport equipment, chiefly the lighting of the port, the airways and landing-fields.

Marking the Modern Air Route. By A. K. Toulmin Smith. Published in *Aircraft Engineering*, January, 1930, p. 11. [A-4]

This article considers the lighting of civil air routes and airdromes for night flying as at present developed in Great Britain.

Der 10. Rhön-Segelflug-Wetthewerb auf der Wasserkuppe i. Rh. 1929. By Walter Georgii, Darmstadt. Published in *Zeitschrift für Flugtechnik und Motorluftschiffahrt*, Feb. 28, 1930, p. 81. [A-4]

With the exception of the Gordon Bennett free-balloon race, the yearly Rhone glider competition, held for the tenth time in 1929, has had a longer life than any other regularly organized aircraft meet or race. That gliding has more significance than merely as a type of sport was first demonstrated by Wolfgang Klemperer in the first competition in 1920, the author asserts in reviewing the history of the event. The next great contributor to the art of gliding was G. Madelung, whose entry in the 1921 event, the Vampyr, set an example in design that was followed through all the later years. The years 1924 and 1925 presented a serious test of the vitality of gliding, for those years saw the restoration of motored-aircraft events, and the air-minded had thus another vent for their interest. However, gliding rallied its adherents and survived this crisis. Since then, the yearly competition has seen steadily improved performances, reaching a ciimax in the 1929 meet described in this article.

The entries numbered 26, and the days of the meet were filled with interesting events, as many as 11 gliders sometimes being in the air at one time. First place for duration of flight went to Neininger, who made six flights that kept him in the air for a total of 24 hr., 3 min., 21 sec., the longest single flight lasting 8 hr., 26 min. In the altitude contest the 1928 record of about 2500 ft. was surpassed, not only once but several times. Distance contests were of three types: the longest flight, the longest flight to a given goal and the longest flight in any given direction.

Descriptions are given of the various important flights, methods of maneuvering employed and barometric conditions encountered.

BODY

Motor-Body Sheet-Steel Operations. By George J. Mercer. Published in *Motor Vehicle Monthly*, February, 1930, p. 15. [B-5]

The tendency to use a greater amount of steel in the manufacture of automobile bodies has completely revolutionized body factories and many of their major manufacturing activities now center around the steel-forming and assembling machinery. The change has occurred so quickly that knowledge and understanding of the various operations required in producing formed sheets that make a body are not yet widespread. The writer proposes, in a series of articles of which this is the first, to describe the various steps in the construction of the sheet-steel parts of the body, dividing the whole into four parts: first, a brief description of the making of the sheet steel; second, the making of the dies; third, the press and allied machine operations; and, fourth, the final assembly operations. These subjects will be treated, according to the author, from both the engineering and shop standpoints.

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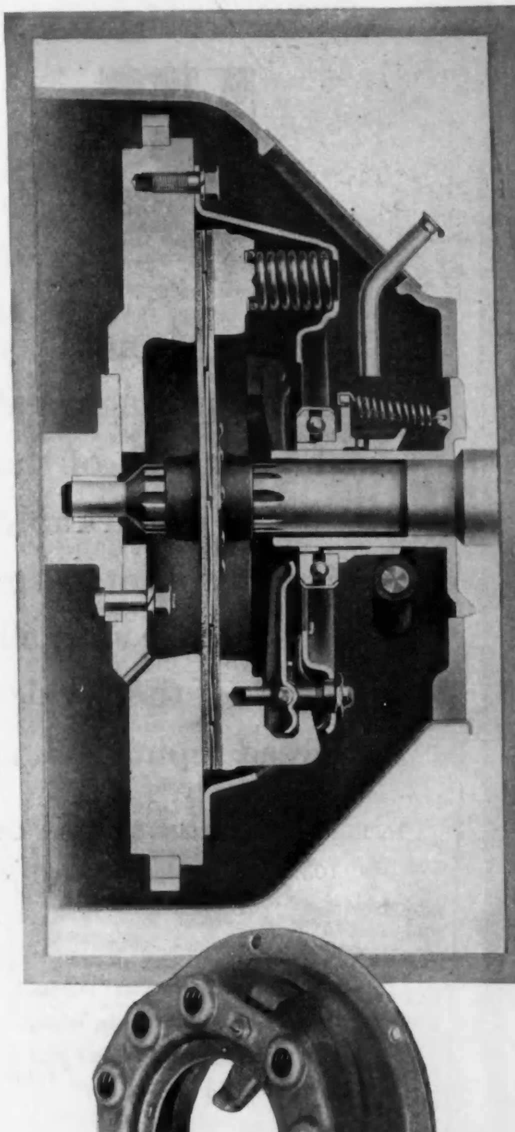

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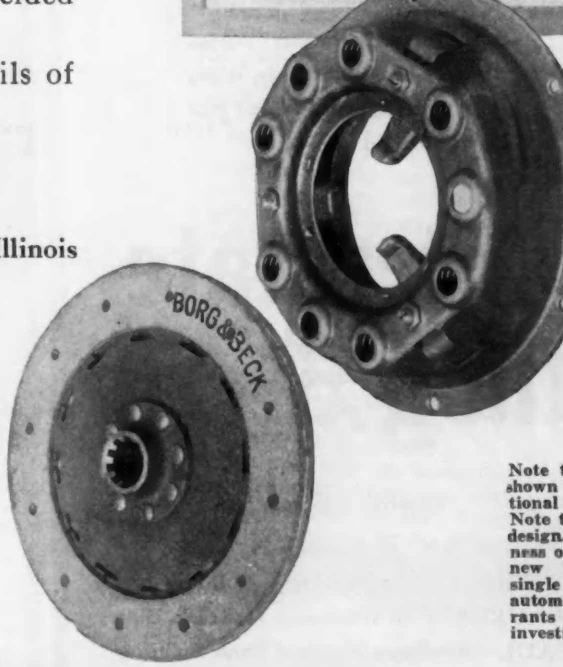

Note the construction shown in the cross sectional drawing above. Note the simplicity of design. The compactness of the unit. The new Borg & Beck single plate clutch for automotive use warrants your immediate investigation.

BORG & BECK

Notes and Reviews

Continued

CHASSIS PARTS

Worm-Gear Drives. By Earle Buckingham. Published in *Product Engineering*, January, 1930, p. 9. [C-1]

In this introductory article of a series, the author sets forth some of the peculiar characteristics of worm-gear drives and tells wherein they differ fundamentally from other types of gearing. He also points out how an exact solution of the problems pertaining to pitch, methods of milling, and lubrication can be obtained by a study of the geometric properties of the warped surfaces of the generated worm-thread.

The second part of the article, which appeared in the February issue of *Product Engineering*, presents equations for the curves of intersection between helicoidal surfaces and planes passing through the axis of the helicoid.

In the March installment the author illustrates by examples how the analytical equations are applied for plotting the worm-thread and gear-tooth form for teeth of different sections.

ENGINES

Application of the Inverse Wiedemann Effect to Torque Measurements and to Torque-Variation Recordings. By Tatuo Kobayasi, assisted by Kinmatu Simamura and Tatuo Koyama. Parts I and II. Reports Nos. 52 and 54. Published by the Aeronautical Research Institute, Tokyo Imperial University, Japan, November, 1929, and January, 1930; total 25 pp., illustrated. [E-1]

The author describes a method of recording, by the application of the inverse Wiedemann effect, the variation of torque acting on a rotating shaft. If a ferro-magnetic wire conducting an electric current is twisted, it is longitudinally magnetized. This phenomenon is termed the Wiedemann effect, the magnetization being given in relation to the longitudinal electric current and to the angle of twist.

The author explains his method as follows: "If a longitudinal direct electric current is passed through part of the shaft by means of contact brushes, the longitudinal magnetization of the shaft part varies as the torque varies. This magnetic variation can be recorded by connecting a coil wound over the shaft part to an oscillograph. This method enables us to record very quick variations of torque, but it is not suitable for recording very slow changes, . . . we can record such slow variations of torque by sending an alternating instead of a direct current through the shaft part."

On the Possibility of Applying the Cathode-Ray Oscillograph to the Indicator for High-Speed Engines. By Jûichi Obata and Yukio Munetomo. Report No. 57. Published by the Aeronautical Research Institute, Tokyo Imperial University, Japan, February, 1930; 8 pp., illustrated. [E-1]

Two years ago the authors devised an electrical indicator for high-speed internal-combustion engines. The indicator consists of three parts; namely, the indicator proper or the part to be attached to the engine-cylinder, an electrical arrangement containing three electrode vacuum valves, and finally a Duddell-type oscillograph with which the record of pressure is obtained.

The present paper contains the results of experiments carried out with the object of applying the cathode-ray oscillograph to the indicator. The Wood, Dufour and Rogowski types were eliminated because of their cost and the amount of skill required in manipulating the oscillograph, which made them unsuitable for use with the indicator. On the contrary, the Johnson-type oscillograph of the Western Electric Co., though somewhat limited in its field of usage, is very inexpensive and was found to work satisfactorily with some modifications of the electrical arrangement, a

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special device being introduced to indicate the piston position. Photographic records of the indicator diagram can be obtained for those engines for which the point-to-point indicator, such as the R.A.E., or Farnborough-type indicator, gives satisfactory results.

Air-Flow through Suction Valve of Conical Seat. By Keikiti Tanaka, Kôgakuhakusi. Parts I and II. Reports Nos. 50 and 51. Published by the Aeronautical Research Institute, Tokyo Imperial University, Japan, October, 1929, and November, 1929, respectively; total 155 pp., illustrated. [E-1]

This paper deals with the experimental research on the air-flow through suction valve of conical seat and its analytical investigation.

At first the experiment on the air-flow characteristics through an ordinary suction valve and seat was studied.

In the second place the experiment on variations of the flow configuration and the flow quantity according to the changes or reformations of the profiles of valve and seat was dealt with. Five changeable points in their shapes are described. By these reformations the flow configuration and the flow quantity vary considerably, and often certain flow configurations disappear. The most effective reformation was the rounding of the sharp corners upon the valve and seat.

Lastly, the result of actual experiment on the Hispaño-Suiza 300-hp. engine, the suction valves and seats of which were reformed by rounding off their sharp corners, is described.

Part II of the report contains the results of the analytical investigation, comparing these solutions with the corresponding experimental results.

Engines and Accessories at the St. Louis Show. Published in *Aviation*, March 8, 1930, p. 470. [E-1]

Among the general trends in airplane-engine design noted in this article are: continued predominance of the air-cooled type; a noticeable tendency toward the inverted in-line type, as exemplified by the display of the new Rover engine, the Curtiss Crusader, the new Fairchild and the Chevrolet engines; and an effort on the part of manufacturers to attain greater accessibility of parts for service. Increased use of S.A.E. Standard mountings is also noted. Improved distribution and manifolding were evident in some cases, as was the work of the General Electric Co. in the development of built-in rotary impellers and the increasing use of aluminum-magnesium alloy castings.

Among the new models described are the Bliss Jupiter, Brownback Tiger, Chevrolet, Comet, Continental, Fairchild, Scintilla, Wright Gypsy, Kinner, LeBlond Lycoming, Lambert, Szekely, Pratt & Whitney Wasps, Rover, Warner Scarab and a number of others.

Fuel Injection with By-pass Valve Control for Diesel Engines Developed by Linke-Hofmann-Busch. By Edwin P. A. Heinze. Published in *Automotive Industries*, March 8, 1930, p. 398. [E-3]

The Linke-Hofmann-Busch Works,, of Breslau, Germany, has introduced a line of five four-cycle Diesel engines for automotive, marine and stationary purposes. The smallest of these, a four-cylinder engine developing 50 to 60 hp. at 1200 to 1500 r.p.m., and the next in size, a six-cylinder engine having an output of 90 hp. at 1300 r.p.m., are intended specially for trucks, motorcoaches and tractors.

The small four-cylinder engine is described with the aid of numerous cross-section drawings. It has a bore of 4.52 and a stroke of 6.49 in. and operates at a compression of 455 lb. per sq. in. The cylinders are of cast iron and in a single block. The separate crankcase also is of cast iron but can be made of aluminum if desired. A fuel-pump

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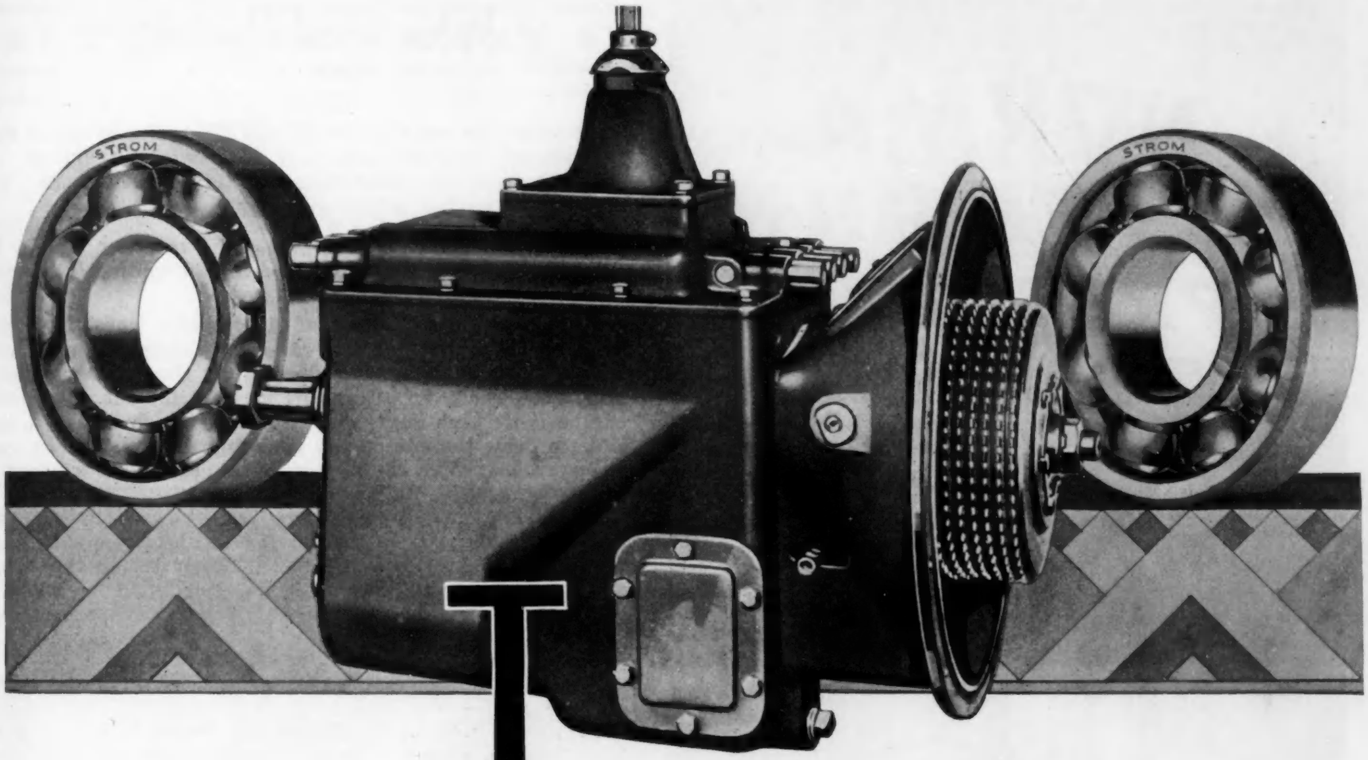
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is provided for each cylinder, and the claim is made that the engine operates smoothly and without smoky exhaust through the speed range of 250 to 1200 r.p.m. The six-cylinder engine is very similar.

Maybach Develops V-12 Engine for Passenger Cars. By Edwin P. A. Heinze. Published in *Automotive Industries*, March 1, 1930, p. 363. [E-3]

After the introduction of 12-cylinder cars in Great Britain by Daimler and in France by Voisin, Germany now follows with a model of this type by the Maybach Motor Mfg. Co. The chief advantage claimed for the 12-cylinder engine is its high degree of flexibility, which makes it possible to drive the car on top gear anywhere except on very steep grades. The car is said to be capable of a speed of about 90 m.p.h.

Both banks of six cylinders and the top half of the crankcase are made in a single casting of aluminum alloy. The Maybach overspeed gear is incorporated in the torque tube and is operated by a vacuum servo.

The article gives a complete description, with drawings.

The Marine Motor. By Frank W. Sterling. Published by the MacMillan Co., New York City; 132 pp., 69 illustrations. Price $2.00. [E-3]

This book was written primarily for motorboat owners but it should prove of interest to motorists as well, since virtually all automobile engines are of the four-cycle type.

The author first outlines briefly the derivation and production of fuels for gasoline and Diesel engines for motorboats and yachts. He then explains the fundamental principles of two-cycle and four-cycle engines, including their construction and operation. The final two chapters are confined to engines of the outboard and the Diesel types. Numerous and excellent diagrams accompany the text matter.

The Lubrication of Aircraft Engines. By F. A. Foord. Published in *The Journal of the Royal Aeronautical Society*, December, 1929, p. 1089. [E-2]

The author, at the outset, urges the closest possible cooperation between the aircraft-engine designer and the oil technologist so that each shall appreciate the other's problems and work toward a compromise that will give efficiency.

"Drawing up specifications for lubricating oils is a thankless task," Mr. Foord declares. "The man is yet to be found who can devise the ideal specification, which will ensure that by tests in the laboratory he can select the most suitable lubricants and also obtain absolutely concordant results when used in the engine." He points out, in this connection, the expense of the laboratory endurance test and turns to a consideration of the ideal characteristics of a lubricant for aircraft-engine work. The characteristics are considered in the order of their importance as follows: viscosity temperature curve, carbonization, cold test, specific gravity, flash and fire-points, and other characteristics.

The article also contains brief descriptions, with illustrations, of the typical lubrication systems and their accessories employed in the most popular English engines. Oil-coolers and cleaners are also considered.

The author concludes with suggestions for further development work. The gumming of the piston-rings, which he points out will be further complicated by the extension of evaporative cooling to aircraft engines, may be improved by the use of ball and roller-bearings wherever possible, the substitution of plain bearings, where used, by the floating-bush type, and the extension of pressure feed to all the more heavily loaded parts.

In furtherance of the policy of using mineral oils, the writer warns that the system of oilways requires careful designing to prevent pockets of sludge forming. As re-

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gards the lubricants, he asks that the oil technologists provide oils that are more stable and do not oxidize so readily, and in this connection calls attention to a patent recently issued to an English firm on the application of dope to lubricating oils.

Progress of Fluid-Film Lubrication. By A. G. M. Michell. Published in *Mechanical Engineering*, February, 1930, p. 114. [E-4]

This paper discusses briefly the problems of bearing design imposed by the increasing demands of modern practice and shows how they are being met in bearings of the film-lubricated type, especially with respect to carrying high intensities of bearing pressure in journal bearings and to increasing the durability of bearings by the elimination of wear. Some commonly unrecognized factors controlling the lubrication of bearings are discussed, especially with respect to lubricants other than oil, and some new types of bearing are illustrated and described.

MATERIAL

Advances in Rubber for the Automotive Industry. Walter C. Keys. Paper presented at the Detroit regional meeting of the American Society for Testing Materials, March 19, 1930. [G-1]

Much is being learned regarding the physical properties of rubber, tremendous strides are being made in the development of rubber compounds for specific uses, and Mr. Keys predicts that the use of rubber will greatly increase. He states that most of the rubber items for automotive uses are compounded with other ingredients such as oil-resisting stocks, gasoline-resisting stocks, adhesion stocks and so forth. Sixty-two items made of rubber, which are to be found in motor-vehicles of 1930, are listed and a number of these uses are described with the aid of drawings and photographs.

Sheet Steel for Automobiles. By W. H. Graves. Paper presented at the Detroit regional meeting of the American Society for Testing Materials, March 19, 1930. [G-1]

This paper deals primarily with the testing of sheet steel for extra-deep-drawn panels, such as body panels and fenders, and the writing of specifications to cover satisfactory steels for these parts.

The author concludes from the studies reported that laboratory tests are more accurate than actual production runs for determining the suitability of a sheet steel for drawing qualities. The Rockwell hardness-tester proved satisfactory in indicating the difference in pressure-ring setting for different steels and also in indicating spring-back, while the Erichsen tester gave an accurate measure of the depth of draw which a sheet steel would stand and showed surface finish after drawing. Inspection, stretcher strains and surface finish are also considered in the paper, and typical specifications are shown for normalized extra-deep-drawing and deep-drawing steels.

A Study of the Ikeda Short-Time (Electrical Resistance) Test for Fatigue Strength of Metals. By Herbert F. Moore and Seichi Konzo. Engineering Experiment Station Bulletin No. 205. Published by the University of Illinois, Urbana, Ill., April, 1930; 31 pp., illustrated. [G-1]

The authors discuss the advantage of having a short-time test for the fatigue of metals and briefly review the methods proposed and practised. The electrical-resistance method was chosen as the most promising and a series of tests was conducted with a modified form of the apparatus used by Shoji Ikeda for his work in cooperation with the Tokyo Imperial University. Armco iron, carbon steel, hardened tool-steel, brass, monel metal and copper were included in the tests.

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Tables of Elastic Properties of Alloys. By C. H. Kent. Engineering Experiment Station Bulletin No. 2. Published by the University of Nevada, Reno, Nev., October, 1929; 52 pp. and index. [G-1]

The tables contained in this Bulletin, as explained in the foreword, were compiled from many sources, most of the data as to composition and elastic properties of ferrous and nonferrous alloys being taken from reports of investigators published during the last 10 years. The principal sources credited are: Proceedings of the American Society for Testing Materials, Circulars of the Bureau of Standards, publications of the American Society of Mechanical Engineers and *Chemical and Metallurgical Engineering.*

The object of the compilation was to present in compact form the compositions and elastic properties of alloys, including the endurance limit, where such information was available, thus making the booklet a reference for design work. The Bulletin covers a comprehensive list of alloys and is well indexed.

Advances in Die-Cast Metals for Automotive Use. By Charles Pack. Paper presented at the Detroit regional meeting of the American Society for Testing Materials, March 19, 1930. [G-1]

The origin and growth of the die-casting process are due almost entirely to the automotive industry, the author contends, and points out that the production curves of the automotive industry and the die-casting industry for the last 25 years, exclusive of the war period, run almost parallel. The automotive industry still consumes over 50 per cent of all the die castings produced.

Die-cast parts for automobiles are being made in increasing quantities from the zinc-base alloys because of the improvements in permanence and in plating technique, which in turn result in economies. Zinc is a less expensive metal than aluminum and its lower melting-point permits the use of less expensive types of casting equipment. The author lists the following parts now cast chiefly from zinc-base alloys: ornamental hardware; speedometers; carbureters; gasoline pumps; ignition, door and tire locks; windshield cleaners; radiator caps; gages and other instruments; oil-filters; ignition systems and car heaters. The paper considers the various die-casting alloys used for these parts classified under: tin base, lead base, zinc base, aluminum base, magnesium base or copper base.

Monel Metal and Nickel Foundry Practice. By E. S. Wheeler. Paper presented before the American Institute of Mining and Metallurgical Engineers, New York City, February, 1930. [G-5]

The rapid increase in the use of monel metal and malleable nickel in the forms of sheet, rod and tube has resulted in a similar increase in the demand for these metals in the form of castings. The successful production of castings of monel metal and nickel requires careful attention to molding practice, proper melting equipment and the application of a definite deoxidizing and desulphurizing treatment.

The author describes the methods used by the International Nickel Co., Inc., which has been engaged in foundry work for the last 20 years.

Commercial Chromium-Plating. By Richard Schneidewind. Circular Series No. 3. Published by the Department of Engineering Research, University of Michigan, Ann Arbor, Mich., January, 1930; 60 pp., illustrated. [G-5]

This circular outlines the essential conditions for good chromium-plating practice. Some of these necessary plating conditions are dependent on well designed equipment, the author points out, and continues with general information necessary for the design of chromium-plating equipment and a description of the mechanism of chromium deposition. The

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defects commonly encountered in practice and typical cost-analysis data are also included. The pamphlet is largely a simplified account of material previously reported in Bulletin 10 issued by the Engineering Department of the University.

Recent Developments in Melting and Annealing Non-Ferrous Metals. By Robert M. Kenney. Paper presented before the American Institute of Mining and Metallurgical Engineers, New York City, February, 1930. [G-5]

The author discusses recent developments in the melting and annealing of non-ferrous metals under the classifications: melting of nickel silver in the vertical-ring induction furnace, electric melting of stereotype metal, the rotary-drum gas-fired brass-melting furnace, the low-frequency coreless induction furnace, finishing annealing of brass sheets with city gas replacing wood in the large brass-rolling mill, electric annealing of brass and copper tubing and sheets, and replacement of oil by gas and electricity in the annealing of nickel-silver shells and stampings.

In conclusion, Mr. Kenney points out that it is now generally understood that a comparison of costs of sources of heat on a thermal basis means nothing without a complete investigation of over-all costs; that profit or loss does not necessarily result from individual process economy; and that the sources of heat best suited to one operation may not fit another. Consequently, there is a definite trend toward the increasing use of the more highly refined sources of heat—electricity and gas—in non-ferrous metallurgy.

Principles of Electroplating and Electroforming. Second Edition. By William Blum, chemist, United States Bureau of Standards, and George B. Hogaboom, electroplating adviser, Bureau of Standards. Published by McGraw-Hill Book Co., Inc., New York City and London, 1930; 412 pp. and index. Price, $4.50. [G-5]

This book has been prepared, not so much for the purpose of presenting the results of research, as of assisting those in the industry to understand and apply the results that have been secured through various research projects and to promote a more general understanding and effective correlation of the principles and practice of electroplating.

The term "electroforming" is defined as "the production or reproduction of articles by electrodeposition."

This second edition has brought all the material uptodate and includes large additions, such as the section on chromium-plating. A group of valuable tables comprises the appendix.

Throwing Power in Chromium-Plating. By H. L. Farber and W. Blum. Published in the *Bureau of Standards Journal of Research*, January, 1930, p. 27. [G-5]

During recent years chromium-plating has come into extensive use in spite of the fact that it is very difficult to deposit chromium in recesses of irregularly shaped articles. General principles show that in the chromic-acid baths used for plating there is little hope of radically improving the "throwing power." The purpose of this investigation was to define those operating conditions which yield the highest throwing power, which at best is poor.

The ratio of the weights of metal deposited on two cathodes, one of which is twice as far from a gauze anode as the other, gives a quantitative measure of throwing power. If, under these conditions, as is invariably true in chromium-plating, this metal ratio is greater than 2:1, the throwing power is negative. The best throwing power obtained was — 13 per cent. Under less favorable conditions it was — 100 per cent or still poorer.

The conditions found to yield the best throwing power are (*a*) a high temperature; (*b*) a high current-density; (*c*) a low concentration of chromic acid; and (*d*) a low sulphate content. These conditions usually require a poten-

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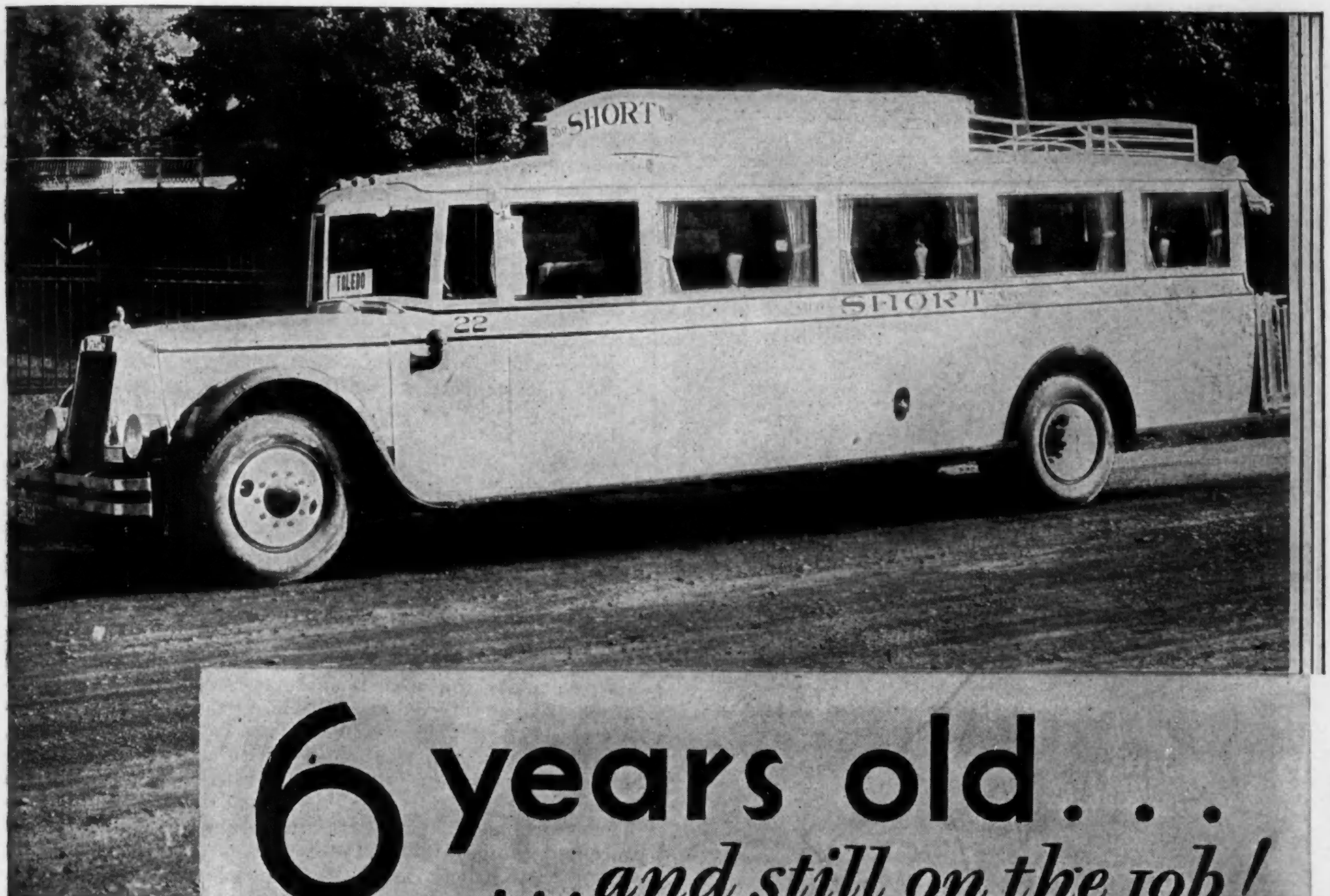

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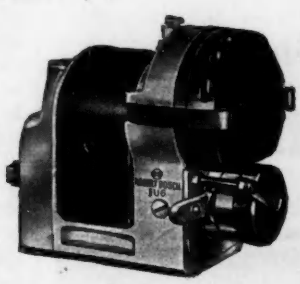

P. S. — Note the Robert Bosch Vibro-Balanced Horn mounted on the side of the coach illustrated above. "We use Robert Bosch Horns on our buses 100%," write The Short Way Lines. "We have some five and six years old that still give good results."

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tial of more than 6 volts. If this is not available, fair throwing power can be obtained in a more concentrated solution with a lower temperature and current density.

The numerical results for throwing power are approximately parallel to the covering power, as measured with copper cathodes bent at right angles.

MISCELLANEOUS

The Effect of Glare on the Brightness-Difference Threshold. By W. S. Stiles. Illumination Research Technical Paper No. 8. Published under the authority of His Majesty's Stationery Office, London, 1929; 63 pp. and diagrams. Price 2s. 6d. [H-1]

For those interested in the fundamentals of headlighting, this paper should offer valuable information based on thorough research starting from the first principles. The methods and results obtained during three years of investigation of brightness-difference threshold at the National Physical Laboratory are reported in detail.

The Thermodynamics of Heat Transference. By A. A. Herzfeld. Published in *The Automobile Engineer*, October, 1929, p. 374. [H-1]

To calculate the various and very complicated thermodynamics of an internal-combustion engine is extremely difficult and is possible only by the use of many hypotheses, contends the author, who endeavors to analyze them in the light of a new theory, with special reference to high-speed engines.

The fundamental idea has been outlined in a dissertation presented to the University of Munich, and the theory is elaborated in a book which Mr. Herzfeld published in 1925. This article treats fully the calculations of the thermodynamics during combustion and expansion in internal-combustion engines.

The article is continued in the November issue of *The Automobile Engineer*.

The Nature of the Physical World. By A. S. Eddington. Published by the Macmillan Co., New York City, 1929; 353 pp. Price, $3.75. [H-3]

Of particular interest to engineers should be the thoroughly matter-of-fact basis on which most modern physicists work. Exactly the opposite impression too often prevails because convenience, if not necessity, dictates the extended use of mathematical symbolisms. But these are only the tools by which the results are attained; and it is the great merit of Eddington's book that he lays the tools aside and deals with broad fundamentals in a way to appeal to the average scientifically minded person. No one need think himself a moron for failing to understand it all.

The first three chapters form a splendid exposition of the antecedents and effects of the Special Theory of Relativity. The next two chapters present a most interesting discussion of entropy as the random element in nature, but is needlessly long and digresses from unchallenged fact to pure conjecture. Then we have two chapters, more or less obscure as to detail, on gravitation (inertia) considered by means of Einstein's General Relativity Theory. There follows a fascinating chapter on Man's Place in the Universe, consisting of practical astronomical evidence on which the author is a first-hand authority. The succeeding two chapters deal with the inner structure of matter and other forms of energy, laying down a few blocks of knowledge but displaying great gaps that still need to be filled; Schrodinger's fanciful but workable theory is here outlined.

Toward the end of the book the author leaves his own field to enter that of philosophy and religion, and, although these chapters are equally interesting and much easier to read, they are not particularly convincing. However, except with a mind open and working, there is no use approaching the book at all. R. H. U.

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Tatsachen und Zahlen aus der Kraftfahrzeugindustrie. Published by the Reichsverband der Automobilindustrie, Berlin; 199 pp., illustrated with charts. **[H-3]**

One of the interesting groups of statistics in this German Facts and Figures of the Automobile Industry is a table giving price-index figures for sales in Germany of passenger automobiles, motor-trucks, machine-tools, small hardware and furniture. The price index is based on the prices of 1913 as 100, and figures are given for each month from January, 1924, through October, 1929. For commodities other than automobiles the trend has been upward with but slight fluctuations in the other direction, until for the last month given the index figures are 150.5, 132.4 and 154.2, respectively, for machine-tools, small hardware and furniture. On the other hand, automobile prices have dropped almost steadily with only minor upward reactions, the latest figures for passenger-cars and motor-trucks being 61.4 and 65.8 respectively.

Like its American predecessor, this pamphlet presents only data, without any editorial comment. The statistics are brought well uptodate, and, for purposes of comparison, figures are also given for previous years.

The first section is devoted to industrial information. This embraces, for Germany, besides the price table mentioned, figures on production, automobiles at present in operation, motorcoach transportation, taxes with especial emphasis on the steady increase in tax receipts from the automotive industry, highway mileage and costs, customs and imports, and tire production. For other countries, the data include production and automobiles in operation.

In the technical section, charts show, for each class of automotive vehicle, the status of various constructional features. A summary of German automotive standardization is also given. An appendix presents certain traffic regulations and reproductions of commonly used speed and road-warning signs.

Technische Jahresübersicht 1929 der Deutschen Kraftfahrzeugindustrie. By Otto Schirz. Published in *Automobiltechnische Zeitschrift*, Feb. 20, 1930, p. 113. **[H-3]**

That the German automotive industry has passed through a fateful year replete with costly crises is the theme of this review of German automotive conditions, industrial and technical. Forced thereto by unfavorable circumstances, both climatic and trade, the German factories have retrenched and reorganized, and even then have not achieved financial security. The steady deterioration in their standing as dividend earning enterprises has been reflected in the falling value of their stock as quoted on the German exchange, these values being in 1929 one-half, one-third and in two cases one-fifth of what they were in 1927.

For the most part this critique is based on the German Facts and Figures of the Automobile Industry, just published, the more significant data being emphasized and commented on. While it is true that the total value of automobiles manufactured in Germany in 1929 showed an increase over 1928, this must not be taken as an indication of prosperity in the native industry, since the proportion of foreign makes manufactured has also increased. An exception to this statement is the motorcycle, the 1929 production of which almost doubled that of 1928, while the proportion of foreign makes suffered a slight diminution.

The balance of imports over exports in passenger-cars, which had been steadily increasing since 1924, showed a recession in 1929, but this is attributed to the activity of foreign assembling plants in Germany, so that a large proportion of what are really imported cars are included in the statistics not under completed products but under parts. For industrial vehicles, the outlook is more promising, for the years since 1924 have seen a steadily increasing export balance for medium-weight and heavy vehicles.

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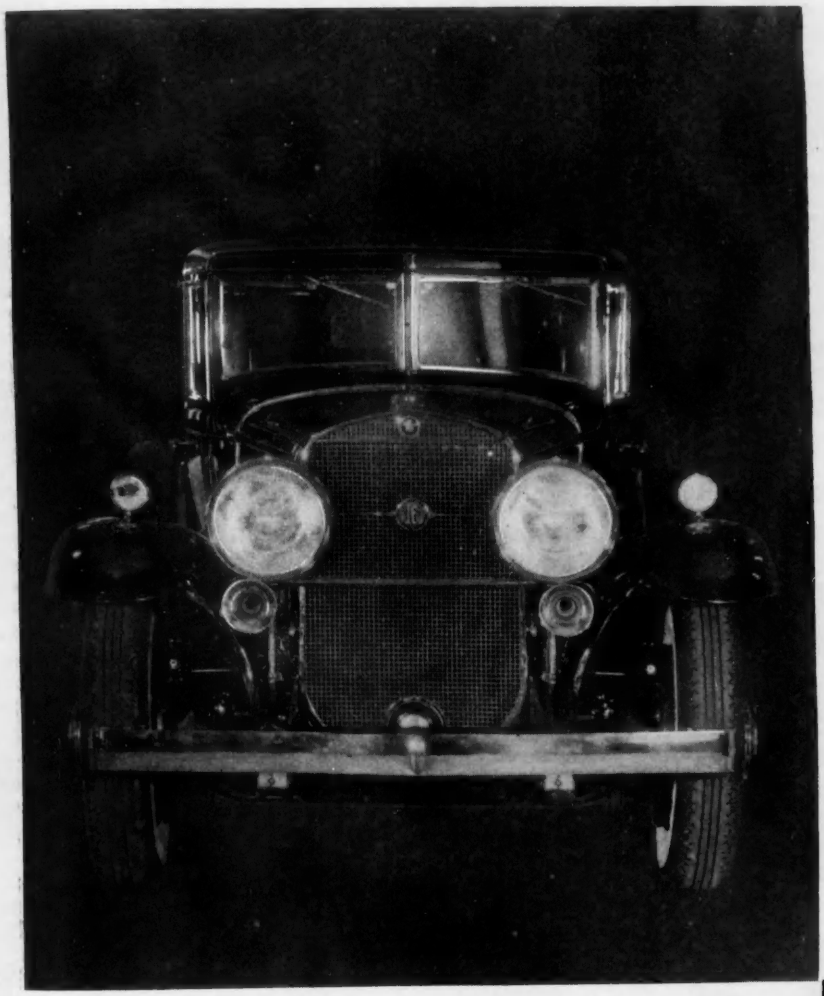

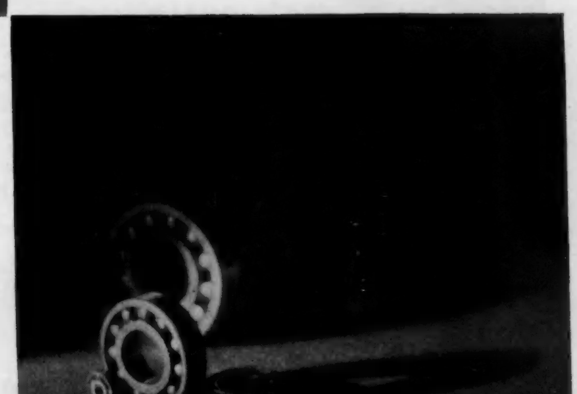

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Among the technical points noted is that every German automobile manufacturer makes his own engines. Among the trends noted are those toward reduction of types, removable cylinder-heads, simpler carbureters, battery ignition, unit engine-gearbox construction and four-speed transmissions. A detailed table of specifications of German cars accompanies this article.

PASSENGER-CAR

The Golden Arrow and the World's Speed Record. By J. S. Irving. Paper presented before the Institution of Automobile Engineers, London, March 11, 1930. **[L-1]**

In this paper Captain Irving presents in detail the design and construction of the Golden Arrow racing car which Sir Henry Segrave piloted at Daytona Beach, Fla., in 1929, establishing a record of 231.36 m.p.h. This information comes at a time when interest in racing is again at a peak, centered on the trials of the Silver Bullet, and, therefore, the data on the underlying characteristics of a high-speed car should appeal to a large group of readers.

A Critical Survey of the Exhibits. Published in *The Automobile Engineer*, Nov. 7, 1929, p. 396. **[L-1]**

This entire issue is an extra number of *The Automobile Engineer* devoted entirely to a detailed review of the exhibits at the London automobile show. In a general summary of design trends, the statement is made that more design work seemed to have been done in 1929 than in previous years, particularly in brake mechanisms, gearboxes, induction temperature control and steering-gears, although the general arrangement of the various chassis appears more stabilized than ever. Improvements have been made more by eliminating known defects from older designs than by change of basic principles.

Components handled by the driver received most attention. Not only the starting, stopping and steering units, but lamp and horn switches, radiator shutters, dashboard indicator dials and so forth all show a standard of appearance and convenience.

In general, it is observed, the size of chassis has increased. They are more powerful, the so-called light cars increasing in dimensions to take bigger bodies, with proportionate increase in engine and gears.

Reasons Behind the 16-Cylinder Cadillac. By Ernest W. Seaholm. Published in *Product Engineering*, February, 1930, p. 52. **[L-1]**

Why 16 cylinders? That is the inevitable question when the new Cadillac car is mentioned, declares the author, who as chief engineer of the Cadillac Motor Car Co. is well qualified to answer the question. The demand for a car that is distinctive in appearance, in performance and in ability to give long service with minimum attention was primarily responsible for the new car design, he states.

The article also covers the various problems encountered in working out the design of this 16-cylinder V-type engine.

Considérations sur les Reglemente des Epreuves pour Viotures de Tourisme. By Henri Petit. Published in *La Technique Automobile et Aérienne*, first quarter, 1930, p. 2. **[L-1]**

In view of the recent discussions in the United States concerning the manner and utility of stock-car races, the reflections of a French engineer on passenger-car competitions, here presented, will be of interest. After emphasizing the thought that the aim of any set of rules should be to assemble the largest possible number of competitors, he indicates what vehicle characteristics, in his opinion, are of fundamental interest and what type of test would most effectively form a basis for judging these characteristics. Finally, as a concrete example, he describes one of France's oldest stock-car events, the Paris-Nice meet. The rules for classification are discussed, as are also tests of turning radius, flexibility, braking and handicap formulas.

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Mechanical Tightening. A Unit of Instruction Manuals for Automobile Mechanics. By L. E. Noble and J. A. Roenigk. Published by McGraw-Hill Book Co., New York City, 63 pp., illustrated. Price $1.00. [L-2]

This is the fourth instruction manual of the maintenance series for automobile mechanics. It is intended to precede Mechanical Adjustments, which is really a continuation and contains further applications of the same principles that are outlined in this volume.

The object of this manual is to give the student a sufficient understanding of the elements of mechanical design so that he shall be able to examine intelligently the parts of an automobile and see that they are in proper working condition.

The manual comprises three chapters devoted to the tightening of chassis, engine and body parts. The authors recommend the student to follow the sequence of instructions as presented and to use the manuals in their proper order so that he will learn gradually from the simple to the complex. In this manner the authors hope to teach a mechanic to analyze and plan a repair job as easily as he performs the manipulative processes.

Mechanical Adjustments. A Unit of Instruction Manuals for Automobile Mechanics. By L. E. Noble and J. A. Roenigk. Published by the McGraw-Hill Book Co., Inc., New York City; 91 pp., 108 illustrations. Price $1.25. [L-2]

The purpose of this manual, the third of the series, is to develop technique for diagnosing and remedying mechanical troubles in the various units of the automobile, such as the brake, front and rear axle, engine, clutch, transmission and the steering-gear.

No attempt has been made to cover all operations in service work that are of an adjustment nature. Certain jobs which are performed frequently in service garages have been selected to provide practice in the essential operations, and such auxiliary information has been included as is necessary for a complete understanding of the fundamental principles involved. When specific instructions are necessary on any make of automobile, the student is referred to the manufacturer's instruction book. Emphasis is placed upon basic operations, and further training is provided in the use of such reference material as will always be necessary in automobile servicing.

In order that the job instructions shall be in keeping with the best practices of today, the authors submitted various sections of the manuscript to manufacturers of such essential parts as axles, steering-gears, clutches and bearings for a check on the correct procedures to be followed in servicing these units.

MOTOR-TRUCK

Continental Commercial Vehicles. Published in *The Automobile Engineer*, January, 1930, p. 9. [K-1]

The commercial vehicle section of the Paris Automobile Salon was a little disappointing from the design viewpoint, the writer states, pointing out that, while several vehicles of exceptional merit were displayed, such as the Mercédès, Saurer, Morton and Renault, the average interest was not high. The exhibits of French origin particularly did not make evident much originality in design, he declares, despite the scope for originality in the design of heavy chassis, apart from the special-purpose vehicles.

If, however, no startling innovations were presented, there was much interesting detail. A considerable number of vehicles were exhibited that were not shown at Olympia, the writer notes. Orthodox four-wheel vehicles, mostly fitted with four-cylinder engines, were the rule, with a sprinkling of tractors and one or two six-wheel vehicles. Main interest centered in one or two new chassis and also some fresh applications of Diesel engines for commercial vehicle work. The most interesting exhibits are described and illustrated.

Personal Notes of the Members

President Edward P. Warner, with **Dr. George W. Lewis** as alternate, will represent the Society on a committee for the preparation of a series of American papers for presentation at the First International Aerial Safety Congress, to be held in Paris from Dec. 10 to 23. **Prof. Alexander Klemin,** also a member of the Society, will represent the American Society of Mechanical Engineers as a member of the committee. The Congress is under the patronage of the French Ministry for Air and the auspices of the French Committee on Aeronautic Propaganda. The American committee was organized by Assistant Secretary Clarence M. Young, of the Department of Commerce, under the chairmanship of Harry H. Blee, of the Aeronautics Branch of the Department.

Joseph H. Appleton, who was consulting engineer on production and design for the Barber-Colman Co., of Rockford, Ill., has severed that connection and is now designing engineer for the Barber-Greene Co., of Aurora, Ill.

Wellwood E. Beall, who has been employed as aeronautical engineer for the Walter M. Murphy Co., of Pasadena, Calif., has resigned this position to take up similar work with the Boeing School of Aeronautics at Oakland, Calif.

E. W. Berry, until recently superintendent of the North Star Silver Lead Mines Co., at Maxville, Mont., is now employed as metallurgist for the Sierra Pintas Mines in Ajo, Ariz.

I. G. Bohrman, former layout draftsman for the Waukesha Motor Co., of Waukesha, Wis., is now employed in a similar capacity by the Hercules Motors Corp., of Canton, Ohio.

Hans Alec Brainders has severed his connection as chief engineer of the Borga Boatbuilding Co., of Borga, Finland, to join the staff of the A. Ahlstrom Co. in Warkaus, Finland.

John A. Carnie, a designer, has relinquished his post with the American LaFrance & Foamite Corp., of Elmira, N. Y., to join the staff of the American Car & Foundry Motors, of Detroit.

P. J. Dasey, formerly district manager for the Buda Co., with offices at Tulsa, Okla., is now a sales engineer for the Oil Well Supply Co., of Bradford, Pa.

Col. Halsey Dunwoody has resigned from his post as vice-president and assistant to the president of the Gardner Motor Co., of St. Louis, to accept the post of executive vice-president of the Universal Aviation Corp., also of St. Louis.

G. Barnett Fairchild is now a member of the sales engineering department of the engineering division of the Buick Motor Co., of Flint, Mich., having been transferred from the personnel department.

R. B. Fisher, who until lately was sales engineer for the Skinner Automotive Device Co., Inc., of Detroit, is now manufacturers agent for steel forgings, with headquarters in Detroit.

Allen A. Floyd has been promoted to the post of assistant sales manager for the Hudson Motor Car Co., of Detroit. He was previously regional sales director for that company.

Theodore O. Gammon is now a sales engineer for the Lyon Metal Products Co., at Aurora, Ill., having recently been transferred from the company's western assembly plant at Los Angeles.

L. W. Greve, of the Cleveland Pneumatic Tool Co., and **J. F. Wallace,** chief engineer of that company, recently sailed for a three-months' business trip abroad, during which time they will survey all of the principal airports overseas.

A. C. Hamilton, until recently consulting aeronautical engineer in the independent field, has been elected vice-president and chief engineer of the Issoudun Aircraft Mfg. Corp., of Northville, Mich.

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Personal Notes of the Members

Continued

Richard F. Hardin, general manager and chief engineer of the Aircraft Engineering Co., of Los Angeles, recently assumed that post after having been vice-president and chief engineer for the Guardian Aircraft, Inc., of Moberly, Mo.

Walter B. Herndon, a former University of Michigan student, is now a layout draftsman with the Cadillac Motor Car Co., of Detroit.

Fred Huep recently joined the triplane division of the Ford Motor Co., of Dearborn, Mich., as aeronautic engineer. He was previously chief designer for the Bolte Aircraft Co., of Des Moines, Iowa.

Lawrence A. Hunt has been transferred from his post in the engineering laboratory of the Ethyl Gasoline Corp., of Detroit, to similar duties in the Ethyl Gasoline Corp. Research Laboratory, of Yonkers, N. Y.

Marion H. Kapps, who has been an assistant field engineer at the General Motors Proving Ground, at Milford, Mich., is now connected with the experimental department of the Chevrolet Motor Co., of Detroit, as laboratory assistant.

Alexis B. Kononoff, former student engineer, has been promoted to the post of assistant motor engineer with the Buick Motor Co., of Flint, Mich.

Charles B. Lewis has resigned his position as secretary of the Bankers Bond & Mortgage Co., of Philadelphia, to enter business for himself as a consulting engineer. His offices are in Philadelphia.

Hector V. Lough has severed his connection with the Carlisle Engineering Works, of Carlisle, Pa., and is now in the independent field as a consulting engineer.

Randolph Matson has entered the service of the Ensign Carburetor Co., of Huntington Park, Calif., as an engineer. He was formerly chief engineer for the Southwest Aviation Co., of Glendale, Calif.

Richard M. Mock, who has been working with the Ernst Heinkel Flugzeugwerke G. m. b. H., Warnemünde, Germany, in a consulting capacity, for the last seven months, has returned to this Country, arriving on April 22 for a business trip of four to six weeks. He is making his headquarters at 107 West Eighty-sixth Street, New York City.

Herbert Morley has been advanced from the post of superintendent of inspection to that of quality manager with the Detroit Gear & Machine Co., of Detroit.

Griffith C. Nicholson, who was an experimental engineer with the Continental Motors Corp., of Detroit, is now chief engineer of the Monroe Steel Casting Co., of Monroe, Mich.

Grayston R. Ohmart, until recently assistant chief engineer for the Absopure Refrigerator Corp., has relinquished that position and is now employed as an engineer by the Kelvinator Corp., of Detroit.

E. J. Opie, former superintendent of engineering and production with the Ramsey Chain Co., Inc., of Albany, N. Y., is now chief engineer and plant manager for the Bailey-Burruss Mfg. Co., of Atlanta, Ga.

Leighton Orr, until recently a member of the technical data department of the Cadillac Motor Car Co., of Detroit, is now engineer with the Pittsburgh Testing Laboratory, of Pittsburgh.

Harry Rose, now chief engineer of Tropic-Aire, Inc., of Minneapolis, was previously automotive engineer in the chassis division of the Buick Motor Co., of Flint, Mich.

B. F. Shepard, chief metallurgist for the Ingersoll-Rand Co., of Phillipsburg, N. J., sailed early in April for a visit to the steel mills in Sweden and other parts of Europe.

A. M. Slagle, former designing engineer for the road-roller department of the Ames Iron Works, of Oswego, N. Y., is now head of the Slagle Bungalow-Car Co., of Oswego.

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Personal Notes of the Members

Concluded

Walter C. Smith, who was formerly general manager and chief engineer with the Vimalert Co., Ltd., of Jersey City, N. J., is now chief engineer and production manager of Murray & Tregurtha, Inc., of North Quincy, Mass.

Frank S. John, engaged until lately in research engineering for the Bendix Aviation Corp., of Chicago, is now a sales engineer for the Long Mfg. Co., of Detroit.

M. F. Streyffert, until recently on special assignment in the export service for the Ford Motor Co. of Canada, Ltd., of East Windsor, Canada, is now engaged in similar work in Singapore, China.

J. G. Swain, formerly vice-president in charge of engineering for the Firestone Steel Products Co., of Akron, Ohio, is now manager of rim sales for the Goodyear Tire & Rubber Co., also of Akron.

Alfred M. Welch has been appointed manager of the New York City branch office of the Federal Motor Truck Co., of Detroit. Prior to making this connection he was assistant manager of the Reo Motor Car Co. of New York.

Vedder White is now assistant district manager for the Autocar Sales & Service Co., of Philadelphia. His previous connection was that of assistant sales manager for the LaFrance Republic Sales Corp., of New York City.

C. G. Williams has accepted the position of chief engineer for the Green Bay Barber Machine & Tool Works, of Green Bay, Wis. He formerly held the position of designer on hydraulics in the experimental department of the National Automatic Tool Co., of Richmond, Ind.

W. A. Wood recently joined the Handy Governor Corp., of Detroit, as a research or experimental engineer. Previous to making this connection he was research engineer in the dynamics section of the Buick Motor Co., of Flint, Mich.

H. L. Zimmerman, until lately assistant engineer with the Nash Motors Co., of Milwaukee, is now engaged in the engineering department of the Briggs & Stratton Corp., also of Milwaukee.

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